



FACULTY OF TECHNOLOGY

Digitalisation of Mobile Application in Construction Industry

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MS Product Management
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Abstract For Thesis

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<p>Abstract</p> <p>There is strong evidence that digitalisation offers the ability to improve or upsurge the productivity and change of information along the whole construction industry supply chain.</p> <p>The main purpose for this research project is to develop ways for the case company to connect its laser distance meters (LDMs) with an existing 3rd party app vendor or self-developed mobile applications to help penetrate the construction trades and respond to customer needs. The research project also represents the major pain-point of customers towards the use of existing mobile applications which support measuring in construction industries. It also aims at finding out whether measurement and data sharing in conventional methods are still used in the construction industry, and to explore the most relevant apps for each construction trade.</p> <p>To achieve the research objectives, key construction trade such as (Building Construction (BC), General contractors or Interior Finishing (IF), doors and windows industries or Steel Metal (SM), architecture metal and facade or Mechanical and Electrical (ME) were analysed constructed on the most relevant measuring application. Mobile apps used by construction professionals were clustered and assessed based on the correlation between app descriptions, price, rating, and popularity details from App Store and the survey conducted and evaluated in their measuring functions.</p> <p>The results of this study lead to the fact that collaborating with key app developers will help to expand services and offering in the construction industry especially in the laser distance meter hardware. Due to that, it will be important to explore the existing trend towards mobile applications which support measuring applications in the construction industry.</p>			
<p>Additional Information</p> <p>Keywords: Construction industry, Laser distance meter, Productivity, Digitalization, Mobile app, Building Construction, Interior Finishing, Steel Metal, Mechanical installation, Electrical installation.</p>			

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Abbreviations

AR	Augmented Reality
BC	Building Construction
BIM	Building Information Modelling
BOM	Bill of Material
DACH	Deutsch, Austria, Switzerland
HVAC	Heating, Ventilation, Air-Condition
IF	Interior Finishing
LDM	Laser distance meter
MEP	Mechanical, Electrical & Plumbing
MO	Marketing Organisation
PM	Product Manager
RFI	Request for Information
SM	Steel & Metal
VPN	Virtual Private Network

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1 Introduction

This chapter introduces the general background of the thesis. It clarifies the aim, research questions and objectives, scope and limitation and validates the need for further research within this thesis.

1.1 Background

Digitalization offers the chance to increase the productivity in the entire construction industry supply chain. Mobile apps play an essential role through this process and provide an opportunity for construction industries to enhance its digital service offering and increase its sales. Deficiency of production efficiency in the construction industry has been the driving force of the development of technology with the aim to modernize the industry and increase potency (AIA 2007).

Construction mobile app are used to create, store, modify access, and organize projects management tasks and plans on a construction site (Son *et al.* 2012).

Mobile technology effect is often seen throughout construction industries which makes it important for the industry to change to digitalization. Vital information is shared from the construction site to the office and vice versa in real-time. This technology has help construction industries tremendously than ever before. With mobile technology evolving it has become more progressive and common on the construction site as companies become conscious of how mobile technologies can simplify and modify the capturing of data within the field and communicate that information to a management ad field teams in a seamless manner. These technologies help construction professionals to decrease errors, increase labor productivity which helps to reduce costs (Morgan 2009, Son *et al.* 2012).

Currently, there are many apps in the market that are employed in construction for activities such as punch list, annotation, markup plans. However, finding the correct mobile app for construction professionals is often challenging. Employing Virtual Private Network (VPN) or Bluetooth at a construction site, documents are shared through mobile app application, construction personnel also remotely access construction estimation and project management (Schermerhorn 2018).

Plans and specifications used for the construction are often measured on constructing site by traditional means which cause a lot of inconveniences. Measurements can be

taken automatically using laser distance meters and transferred onto a mobile app which is to be shared with managers within the office or site supervisors.

A construction mobile app can transfer measurements and construction documents in Drop Box, cloud storage and file hosting service by synchronizing with laser distance meter (LDM). The utilization of this allows easy accessibility of files to be placed in a folder through a website. For instance application such as fieldwire, magicPlan allows construction workers to view, annotate, and communicate project information from a mobile device which also helps them to view details, zoom in and out to see the detail of a plan and migrate from the drawing as needed. The mobile applications allow construction professionals to further annotate plans, develop Requests for Information (RFI) using a text feature contained within the application, and attach photos of a construction site or an item needing clarification. Further, using the LDM, RFI documents can be sent directly to instructors who can rapidly respond to the RFI by uploading revised drawings or providing written clarification. (Cline & Davis 2013, Son *et al.* 2012).

1.2 Research questions and objectives

The purpose of this study is to discover the Apps within the market that are employed in the life cycle of a construction project. One of the questions this study aims to answer is: What are the existing mobile applications (iOS & Android) in the market and their potential in the construction trades? The research critically observes those apps which are used by professional construction workers via semi-structured interviews. After clustering the Apps, it was reviewed and assessed based on the correlation between app descriptions, price, rating, and popularity details from App Store and the survey conducted and evaluated in their measuring functions.

It also aims at pain-pointing the use of mobile apps used by some construction professional. Which construction related mobile applications (apps) exhibit a relevant potential to increase the trade-penetration with mainstream laser distance meters. With this information, potential construction app-vendors can be approached to collaborate with or a well-defined roadmap of the mobile application can be developed in-house. The growing of digitalization is one of the vital trends that will elevate the growth of the laser distance meter market in the coming years.

Digitalization offers the opportunity to increase the productivity along the whole construction industry supply chain. Mobile apps play a central role in this process and offer an opportunity for companies to improve their digital service offering and increase

their sales. A lot of companies in this competitive market segment have a wide range of popular measuring apps and collaborate with other app providers. Basic comprehension of the goals, purpose and the importance of digitalization to improve productivity in the construction industry must be covered. More so, the research provided basic measuring relevance of using laser distance meter in the construction trade for a value proposition.

Another goal of this project is to develop ways to connect laser distance meters with existing or self-developed mobile applications to respond to customer needs, expand service offering in construction industries and further penetrate the construction trades. It also aims at analyzing customer needs with respect to mobile Apps for laser distance meters. The research conducted through interviews with professional construction workers and internal surveys with product managers and key account managers who have direct interaction with customers in each construction trade. This procedure can help to gather information for future assessment and can help identify the basic needs of customers and provide them value for their money.

The last and important objective for this research is to give a recommendation on the apps that can be integrated with laser distance meter without any hassle when used by customers.

The following questions must be answered to fulfill the objective of this research:

RQ 1: What are the most relevant measuring/documentation tasks in construction trades?

Most construction workers still document measurements in a conventional way or directly in the architect plan and later copy them into PC-based software for material ordering and final costs justification. Data are mainly shared via the architect who holds together all the information about the construction object. This research question aims at finding the processes in the construction industry where measuring or documentation is relevant and also find out whether these measuring or documentation and data sharing are still recorded or done in a conventional way.

RQ 2: What are the major pain-points and challenges construction workers face in measurement and documentation tasks with LDM?

The goal of this second research question aims at finding key challenges of measuring with an LDM tool and the circumstances surrounding the difficulties in using LDM on the construction site. And, high error rate when transferring measurements, offers great potential for app-based documentation solutions.

RQ 3: What are the existing mobile applications (iOS & Android) in the market and their potential for laser distance meter in the construction trade?

The third question aims at exploring the existing trend towards mobile applications which support measuring applications and the most relevant functions of a mobile app for laser distance meters.

RQ 4: What are the most relevant apps for each construction trade and their business potential?

The fourth and final research question main objective is to evaluate existing mobile applications with the biggest potential for LDM customers in construction main-trades.

The summary of the research questions and objectives is shown in table 1 below.

Table 1: Summarization of research questions and objectives

Research Problem	Research Question	Aim/Goal of Research
Most construction workers document measurements on paper or directly in the architect plan, this cause low productivity and lack of efficiency.	What is the most relevant measuring/documentation tasks in construction trades?	This aims at finding the processes in the construction industry where measuring or documentation is relevant and also find out whether these measuring or documentation and data sharing are still recorded or done in a conventional way.
There is concern of technical ability for construction workers to use and understand the integration of LDM and mobile app	What is the major pain-points and challenges construction workers encounter in measurement & documentation tasks with LDM?	This aim at finding key challenges construction workers encounter when taking measurements with LDM tool and the circumstances surrounding the difficulties in using LDM on the construction site.
Finding the correct mobile app for a construction trade is very challenging and difficult for construction professionals.	What are the existing mobile applications (iOS & Android) in the market and their potential for laser distance meter in the construction trade?	The aim of this research question is to find mobile apps which support LDM to make measurement easy and convenient.
Deficiency in productivity efficiency in construction industry is a major blow for construction industry.	What are the most relevant apps for each construction trade and their business potential?	The goal is to assess the existing mobile apps in the order of their measuring functions which can help increase labor productivity.

1.3 Scope

This thesis is limited to giving details of the construction business process, only process with measuring relevant are going to be highlighted. More so, only selected focus trade that has higher market shares for the case company will be analyzed further.

The internal survey in this thesis will not be discussed into details due to confidential issue with case company. The results of the internal survey were analyzed internally and are not allowed to be shared. Furthermore, the Finnish survey will not be discussed into details because the respondents were not the targeted group for the study.

2 Theoretical Basis and Market Analysis

This chapter reviews the historical aspects of construction industry and productivity and the current trends in the usage of construction mobile apps and consideration of integrating laser distance meter with mobile devices in the construction industry.

2.1 Construction industry and productivity

Construction remains one of the world largest sectors within the emerging economy which employ about 7% of the working population. The Construction industry in the developed world has been growing since 2014 with a positive prospect in 2018. Even though construction matter to the world economy, it has not been able to match the productivity growth of the total economy and misses to add a value of as much as \$1.6 trillion a year which would equal a 2% growth of global GDP. (Baumanns *et al.* 2016, McKinsey 2017).

There are four main areas which affected the productivity in the construction industry, expects see it as a megatrend which should be investigated to reshape the industry. These areas are markets and customers, sustainability and resilience, society and workforce, and politics and regulation (Renz & Solas 2016).

These areas can be boosted in the construction industry to raise the economic growth to about 50-60%. These can only be achieved by completely increasing (McKinsey 2017):

- The use of professional tools to accelerate the progress of daily tasks, new materials adaptation and technology across digital advanced automation.
- Regulation through work should be set up to reshape the industry.
- There should also be integration between contractors and subcontractors to rewrite a contractual framework.
- There should be technical know-how in the design and engineering process and rethinking of how to use prefabricated design models in the construction industry.
- Supply chain and procurement management must be optimized to increase labor productivity.
- More training should be done to enhance developing the workforce.
- Finally, onsite technology should be adopted to facilitate the working process.

When all these measures are put in place, there is a tendency the industry can grow more efficiently and can add billions of dollars in the global GDP, but these can be achieved when all stakeholders take part to break the current deadlock. (KOF 2017, McKinsey 2017).

Digitalization, on the other hand, allows for greater productivity in the construction business which helps to increase productivity along its supply chain focusing on opportunities arising from emerging technologies. (Baumanns *et al.* 2016, McKinsey 2017).

There are four main major areas which the construction industry must shift its focus on which are: digital data, automation, connectivity, and digital access. (Baumanns *et al.* 2016, KOF 2017, McKinsey 2017).

In the developed world infrastructure is an essential part of the economic growth, and before developing countries can attain a sustainable and balanced growth efficient and modern infrastructure is very important. The construction industry is a major player in the global consumer of steel production which amounts to 50% and 3 billion tonnes of raw materials which are used to produce building products. (Renz & Solas, 2016).

According to International Monetary fund, it was estimated in 2014 that, if developed countries invest an additional 1% of their GDP into infrastructure construction, they would achieve a 1.5% increase in GDP after four years of their investment. This indicates how important construction industry can transform the economy of the world. (World economic outlook 2014).

It is therefore very important to find a suitable way to add value in improving the quality of the construction industry, thereby contributing to the sustainability of the environment and reducing cost.

2.1.1 Construction industry trend

It is very important to acknowledge the fact that construction industry is somewhat different from other industry sectors, such as manufacturing, this makes the construction industry very challenging to drive productivity growth. For example, in construction industry unpredictable weather condition can make a project overlap with each other. These entire uncontrollable variables make it lots difficult compared to other industry sectors. (Baumanns *et al.* 2016).

There is always misalignment between working in the office and the execution of work at the construction site. It is very important to adopt new technology and innovation so

that a contractor can be in the digital journey to know if a contract is less mature they can make some very quick wins regarding driving productivity. (KOF 2017).

In the world of technology best practices in the construction industry is pushing digitalization of using web packaging techniques which allow construction workers to use mobile devices on site to capture issues and transfer it to the office. These trends stem from changing requirements of building owners regarding energy efficiency, modern technology, security, comfort and design and have the potential to significantly change the construction industry as shown in figure 1 below. (Baumanns *et al.* 2016).

In addition to construction companies that are already using 3D BIM, 4D BIM for many years it will be prudent to start looking into the fifth dimension BIM which is using techniques such as earned value management to constantly analyze actual cost and actual progress against the baseline plan. With this, the newly gained knowledge, industries can make progressive corrections to keep a project on its track. (KOF 2017).

Furthermore, many contractors in the construction industry are turning to machine control and automation. They are using tools like robotics total station to facilitate the faster setting out and laying out the construction site. As a result, an increased use of reality capture devices such as laser scanning to take scans and get live progress updates from the field. (Renz & Solas 2016).

Best practices assist to improve the planning execution phases in the construction industry. Intelligently linking cost and schedule information to a 3D model during the planning phase of a project and then monitoring actual costs and actual progress during the execution phase of the project. (Baumanns *et al.* 2016, KOF 2017).

Mobile technology used by construction industry drive productivity both on the site and the back office. This can reduce the amount of time spent on non-value adding activities; repurpose those times to save into work that is going to benefit the worker. (Baumanns *et al.* 2016).

To improve productivity, the ease of using software is very important and should be very intuitive. People don't like to be displeased by technology, so it must be easy to use to get them adopted. (McKinsey 2017).

More so, information that is assigned to the workers in the field must be timely and conceptual to the role they are performing. The pursuit of productivity in construction must be done in a responsible way, this is because construction influences all other industries, and therefore the productivity within the construction process must be improved. (McKinsey 2017).

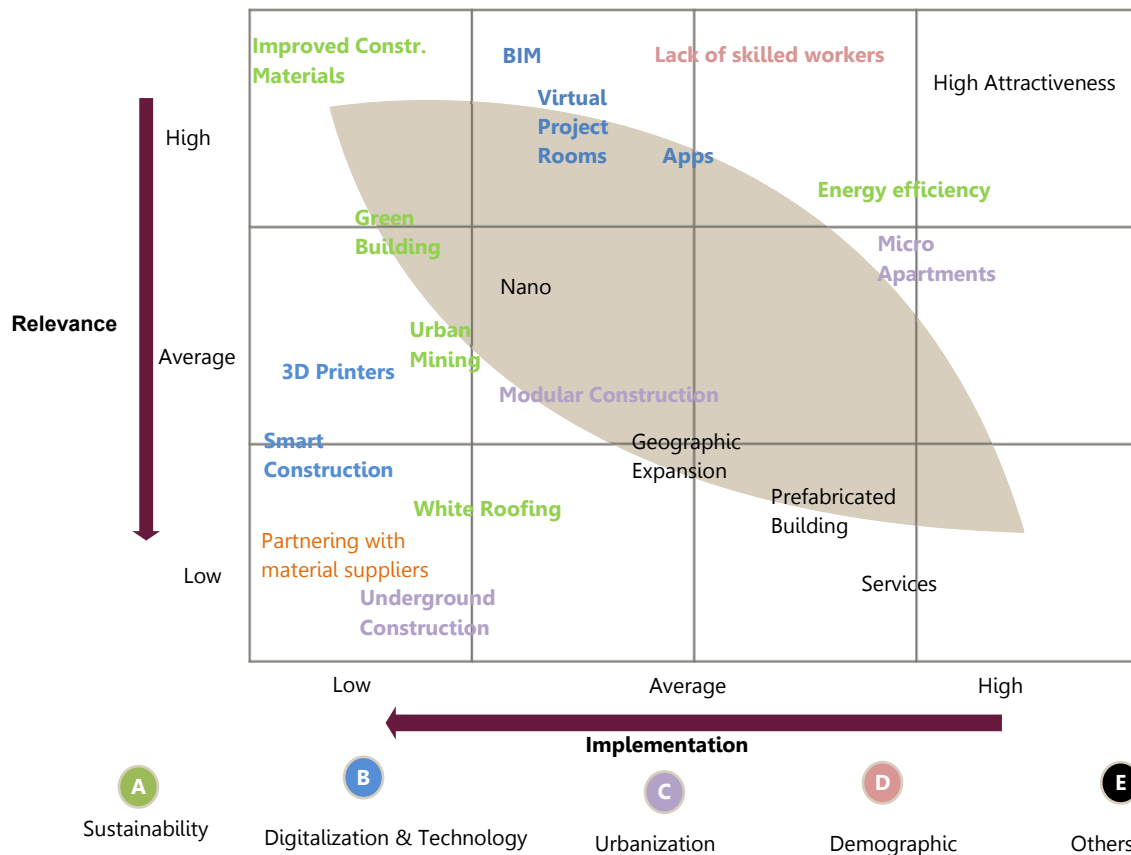


Fig 1: Changing efficiency in the construction industry (modified from Baumanns et al. 2016).

2.1.2 Opportunity of digitalization

“There is no alternative to digitization. Even on the building site. Construction needs to catch up.” (Baumanns et al. 2016, p.3).

The growth of digital technologies and processes is an essential part required in the transformation of the construction industry. Digitalization helps to improve the construction industry and with the right tool for construction workers there will be efficiency and productivity onsite. Connectivity in the digitalization world of construction tools will yield a significant benefit for the industry focusing on digital data, automation, connectivity, and digital access. (Baumanns et al. 2016, McKinsey 2017).

Some of the opportunity construction companies face depending on the size of the business; the market trends offer different opportunities and challenges. Table 2 shows

some of the opportunities and challenges faced by these companies. (Baumanns *et al.* 2016).

Table 2: Market trends offer different opportunities and challenges (modified from Baumanns *et al.* 2016).

Size	Opportunities	Challenges
International groups	<ul style="list-style-type: none"> ▪ Benefit from digitalization by having enough funds to invest in new technologies/know-how and thus to establish a head-start. ▪ New large projects thanks to urbanization ▪ New business fields thanks to sustainability 	<ul style="list-style-type: none"> ▪ Revolutionary business models from start-ups that are more flexible ▪ Lack of skilled workers
Middle sized companies	<ul style="list-style-type: none"> ▪ Simplification of their processes (e.g. planning) through investments in new technologies ▪ Are already active in the sustainability field and thus can leverage on their head-start 	<ul style="list-style-type: none"> ▪ Lack of skilled workers ▪ Competition between building construction(e.g. for refugees)
Local construction companies	<ul style="list-style-type: none"> ▪ Should focus on projects which depend on subcontractors. ▪ Can build up expertise regarding sustainability 	<ul style="list-style-type: none"> ▪ Digitalization as a challenge since local companies do not dispose of enough funds to invest in new technologies
Specialized companies	<ul style="list-style-type: none"> ▪ Will be more demanded thanks to the sustainability and urbanization trends that require specific knowledge ▪ Can be successful subcontractors by mastering new technologies 	<ul style="list-style-type: none"> ▪ Lack of specialists

Construction industries today are facing challenges in the digitalization world since many of the industry cannot follow the rapid enhancement of innovations. These changing trends present an opportunity for the growth of the construction industry. However, "Building Information Modelling" (BIM) system, used in many countries, frequently considered as the "Industry 4.0" of the construction industry, is still in its early stages in Germany. (Irene *et al.* 2018).

“According to a study by the Association of German Chambers of Commerce and Industry (DIHK), about 93% of companies agree that digitization will influence every one of their processes”. (Baumanns *et al.* 2016, p.3).

The implementation process of digitalization by using “Building Information Modelling” (BIM) can be seen in figure 2 below. These can be divided into three main phases which are 3D Design (i.e.: Visualization, coordination, cooperation), Integration (i.e.: Design and analysis, Design and cost estimation, Design and planning) and Industrialization (i.e.: Detail design, supply and logistics, Production). (Kunz & Fischer 2012).

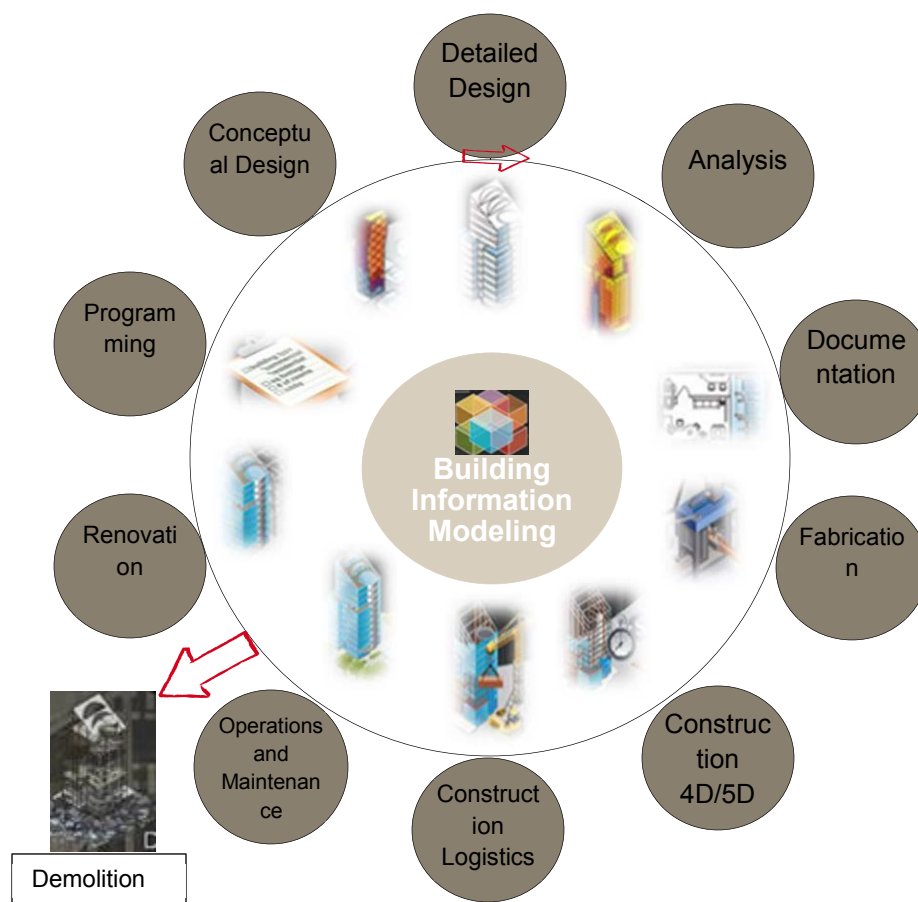


Fig 2: Implementation process of digitalization by using “Building Information Modelling (modified from Kunz & Fischer 2012).

2.1.3 Mobile apps in construction industry

Mobile apps increase productivity on construction sites which is essential in today's construction industry for its critical to success. Mobile app technology allows engineers and contractors with an instant design changes when some measurements taken are wrong. With the help of mobile devices this change can be done either in AR (Augmented reality) or a construction design plan on their tablet, this is how the industry is fast changing with the help of innovation and technology. Engineers, foremen and architects can also sketch, make changes, punch list, give comments and suggestions, make cost estimations, workflow of information and propose improvements that can be shared with anyone in the office or to a client. This technology process can improve the efficiency of the construction industry. (Adriaanse *et al.* 2004).

“In general, some researchers have reported that mobile computing is yet to have a significantly positive impact on the construction industry as IT innovations have been adopted in a piecemeal fashion.” (Venkatraman & Yoong 2009, p.3).

The fast technology enhancement in the construction mobile apps allow contractors and engineers to record and view activities going on construction site, they can get a forecast of the weather and calculate labor productivity. Project managers have access to project directories and can attach any changes done in drawings and punch list item to other colleagues in the office. Calculation is one of the key aspects in construction mobile application which allow BOM (Bill of Material) calculation and measures volume, area, Pythagoras, stack function and continuous measurement. (Adriaanse *et al.* 2004, Baumanns *et al.* 2016).

Construction mobile devices have become a productive tool within the construction industry. These construction mobile apps have helped many construction industries to save money and have created effective collaboration between clients, suppliers, site workers and customers to work more productively and effectively. (Chien *et al.* 2003).

Engineers or architects can upload or download plans in a digital form as they work or send it by email to other colleagues or project manager. Work routine can be schedule by using the construction mobile app, in that case the site manager can easily know how many workers are onsite or who is absent, and this helps the companies to save money and cost of labor. (Cline & Davis 2013).

Mobile apps are being also a best solution for tracking labor hours and equipment in the field, while it has all these advantages it can also be integrated to other platform which documents can be shared through SharePoint, drop box and google drive. It is a great tool which can help reduce project delivery inefficiencies. (Mobile Man 2015, Son *et al.* 2012).

According to Sage Software (2016), construction projects are becoming very complex and because of that, mobile technology is used to reshape the industry, out of 1500 construction professionals surveyed, majority use construction mobile apps to retrieve customer and job information (68%) for fast analysis, followed by drawings, photos, and documents which is (67%), daily field reports is approximately (76%), job cost and project reports (61%), time capture schedule (47%). (Sage 2016).

2.2 Measuring and documentation in construction trades

Documentation and measuring play a major role in the construction industry, it helps to streamline processes and update vital information on construction site. Architect and engineers document information in real-time without any hassle or leaving the construction site, furthermore, the foreman or project manager can review, make changes and make sure all necessary information and updates are amended before the workers leave the construction site. This help to eliminate any impending hazard on the construction site and improve information sharing, a correction which greatly advances productivity and efficiency. (Riddell 2017).

In the construction industry measured drawings are fundamental, it is the formalized product of documentation, which helps the architect and the engineers to have a blueprint and information they can work with. These documented drawings help the engineer or architect to observe, analyze, measure and interpret easily. (Nakashima 2010, Serra 2017).

Documentation often contains tender which has all vital information which a contractor and subcontractor can use to estimate project cost. Project plans can be marked and upload as PDF, create task for employees and sub-contractors.

Usually, documentation is produced by the architect, structural engineer, civil engineer, foreman that are used to provide pieces of information such as drawings, specifications, schedules, bill of materials (BOM) etc. Construction trades which make use of documentation and measurements are structural steel, building construction, electrical and mechanical installation and interior finishing, this help to ease their work and provide quality of document for a finished project. (Laryea 2011, Riddell 2017).

Documentation can help ease the evaluation of measurement records made by workers, and this can promote greater efficiency when engineers and architect are assigning to do a different consignment. Documentation helps to prepare the worker to successfully complete work on the onsite and maintain progress on site. This also helps to decrease the effort of producing measurements and calculations supporting the final

contract records upon finishing a project. Project engineers usually are the ones who are responsible to ensure that documentation and accurate measurements are done and recorded during construction project work. (Khaleghi 2010).

These measuring functions can help boost labor productivity. With the conventional method of documentation and data sharing, foremen, project managers and architects will find it difficult to work with the correct data. This can affect the productivity of construction onsite.

2.2.1 Insight to Laser Distance Meter usage

Distance measurement is a very important part in today's construction industry to optimize efficiency and improve sustainability. Distance measurement is used in almost all works of life such as engineering, scientific research and infrastructure, with this it shows how important laser distance meter can help us progress and work efficiently in our different sectors.

A laser distance meter (LDM) uses a laser beam to send a pulse of light to a target and measures the distance of the targeted object and the time it takes the pulse to be reflected. Laser distance meter is a convenient way to add, subtract and calculate areas, volumes and trigonometry of a distance on like the old fashion conventional way of measurement with tape. Due to the high speed of light it transmits, it is accurate than Ultrasonic laser meter. (Seubert 2017).

The basic principle behind a laser distance meter is that it emits a pulse of light to a targeted object. A laser beam is reflected by a beam splitter which then generates a sinusoidal signal with constant amplitude and phase by two prisms on a photodiode. The avalanche photodiode detects the reference of the signal beam which then acts as a phase measurement of the signal coming from the detector; this then converts the measured time to distance. (Bartolini *et al.* 2000).

An Ultrasonic Distance Meter on the other hand has the same principle but uses sound whereas laser distance meter uses light. It is easier for time measurement with Ultrasonic since the speed of sound is just about $\frac{1}{3}$ of a km per second. A laser distance Meter is a more accurate in comparison to Ultrasonic distance meter which has a lot of interference when it is blocked by an obstacle. (Transcat 2018).

On like the traditional method of taking measurement which results in multiple errors, laser distance meter helps to record measurements with ease and provide precise measurement of dimensions.

More construction workers are complaining their clients demand on accurate result and data documentation to be shared with them. This causes higher demand for laser distance meter, which will continue to rise in coming years. (Riddell 2017).

2.2.2 Insight to app usage

Most construction workers use apps for their daily tasks and value simplicity. These apps are used by construction workers to reduce delay at work site. Real-time information is gathered by using these apps to avoid project delay. A delay can put a project on hold keeping construction on schedule. These app have improved the way project stakeholders handle project task and how easily it helps them to send report automatically from construction site to the project stakeholders, these reduces error, and everyone has access to the right information. (Joyce 2011, Son *et al.* 2012).

According to Abaffy (2011) there are two main benefit of using construction mobile app and these are time and cost saving. Stakeholders in construction project depend on accurate data documentation and real-time information to succeed in any project. It is important to share information on the construction site to avoid delay and time wasting to achieve the project timeline set for a client. There are many apps that are available in the market to help construction professionals to accelerate in their work and share information in the office with the stakeholders without having troubles communicating. (Son *et al.* 2012).

It has been realized that the traditional form of transferring construction document or measurement such as drawings, data documentation, real-time information and specifications are done on paper. These cause low labor productivity on the construction site and lack of efficiency. (Bowden *et al.* 2004).

Mobile apps, in general, are used for productivity and information sharing, the use of mobile apps has increased and expanded rapidly due to the demand of users. The most popular app category among Android and Apple iOS users in the construction field is photo and document sharing, checking of weather, sharing of information on the construction site. (Joyce 2011, Adriaanse *et al.* 2004).

The increase use of laser distance meter is due to the growing number of construction mobile application in the market. There is a continuous integration of laser distance meter with in-house app or 3rd party app vendors on a real-time basis and this has resulted in an effective productivity in the construction industry as well as reduces the challenges in taking measurement at a construction site. (Transcat 2018).

2.2.3 Integrating apps and Laser Distance Meter

Taking measurements with tape measure and calculating the measurements on a piece of paper with the help of two or more people is a thing of the past. Nevertheless, tape measure is still widely used in our everyday life which we cannot do away with. Integrating a mobile application with laser distance meter comes along with Bluetooth capability which allows the transfer of data from the laser distance meter to the app for accurate documentation. (Seubert 2017).

Most construction mobile application allows creating sketches of objects or layouts of a room. Dimensions or measurements of the room are automatically created into the app making it very easy and convenient. It helps construction worker to transfer documentation at construction site remotely to other project stakeholders. (Bowden *et al.* 2004).

It is difficult for construction workers to integrate mobile app and laser distance meter. This is because most of the construction workers lack training and technical ability for them to use and understand the importance of the device at the construction site. To be able to achieve this construction industry should provide necessary training to their employee on how to integrate, view documents and use the device at the construction site. (Joyce 2011, Tam 2000).

This will increase the use of mobile apps and laser distance meter on the construction site and can facilitate the productivity of the job. Construction workers will not feel reluctant to use the mobile app at the construction site if proper education is given to them because it will speed up their work, help them check quality control and view documents on construction site without going to the office. (Tam 2000).

It can be concluded that, the relatively poor economic growth rate of construction industry is ineffective communication between constructions worker that has contributed low productivity. Mobile application on the other hand provides more opportunities for data collection and documentation to improve workflow efficiency. (Bowden *et al.* 2005, Chen & Kamara 2008, Löfgren 2007, Mohamed & Stewart 2004, Weippert *et al.* 2002)

3 Methodological Approach

This chapter describes the process and difference between research strategies; research design, research process and research methods used in the study. It gives detail explanation on how each process was considered in the research.

3.1 Research strategy

The research study conducted in this thesis is to find solutions to the low differentiation of laser distance meter hardware and to explore the existing trend towards mobile application which supports measuring in the construction industry. The researches in chapter 1.2 RQ1 to RQ4 were therefore framed to fit this purpose, by using a “what” format.

The research strategy which is considered in this study is the mixed method design which integrates procedures from qualitative and quantitative method to answer research questions. This method helps the researcher to answer confirmatory and exploratory questions at the same time and as a result it helps to construct and confirm theory in the same study. (Teddle & Tashakkori 2003, Morse 2003).

There are two ways to define the relationship between theory and research to produce a quality result and these are called inductive and deductive. In inductive approach, data gathering, and observation method is therefore used to produce theory, while the deductive methodology starts with theory from which hypothesis is taken and therefore verified by data gathering. (Bryman & Bell 2015).

The common combination of inductive theory is qualitative and quantitative data collection in mixed method design. This method was therefore considered as suitable for this research because it allows the researchers to make good use of earlier research work when developing a valuation framework which will be used to develop new concept and also help to explain the relationship found in the qualitative data based on the collected quantitative data. (Bryman & Bell 2015, Morse 2003).

Epistemology is considered as what is appropriate to understand knowledge within the context of its validity and method of the process and how we can use resources to acquire knowledge. There are two types of epistemology which are positivism and interpretivism. Ontology is a theory which distinguishes between different types of objects and their dependencies. There are two types of ontology which can be referred as objectivism and subjectivism. Interpretivism is used to get an understanding and

knowledge of questions from a different method that is yet to be considered. (Bryman & Bell 2015). A positivism epistemology cannot be considered because there were very inadequate literatures to directly deduce hypothesis from.

3.2 Research design

The research design shows how the researcher answers the research questions to achieve its purpose. Considering the research questions, the ideal way to get more knowledge and understanding of the problem and find a possible solution to the problem is to explore the dynamic changes in the construction industry in terms of laser distance meter integration with construction mobile app. This has not been considered in current literature and this study was therefore intended to explore this area. (Saunders *et al.* 2015).

There are three main ways of conducting exploratory research which was defined by Saunders, Lewis and Thornhill (2015): these are interviewing experts in the research, exploring of literature to find information about the research question and, conducting focus groups. The research in this thesis is going to be based on interviewing experts in different construction trades as the focus group to help answer the RQ1 to RQ4 and searching for literature to support the theoretical part of the research. The purpose and way of using these methods are described in the research methods sub-chapter. This method is very flexible since it is easy to change direction because of the new data and new insight attain during the research. (Saunders *et al.* 2015).

The formulation of the research questions indicates that some specific trades in the construction industry need to be analyzed to get a comprehensive answer (E.g. in RQ1 'what the most relevant measuring/documentation tasks in construction trades are?'). The construction trade experts who were interviewed are Building Construction (BC), Interior Finishing (IF), Steel-Metal (SM), and Mechanical & Electrical Installations (M / E). An emphasis was also put on conducting an internal interview to product managers and key account manager of market organization (MO) since they have direct contact with the customers.

An internal survey was conducted targeting the leading sales organization/HUBs and a total of 34 product managers (PMs) and key account managers who have direct access to customers were interviewed to get their feedback and understanding whether the local customers use construction mobile application in the daily work of life and which application (App) is most relevant in their trade. As described in the scope and limitation of this thesis, these process and result is not going to be discussed further.

The second analyses were to conduct an external survey to ask the constructions experts their major pain-points and challenges face in measurement and documentation tasks when using laser distance meter where 161 participants completed the survey. The focus trade was Building construction (BC), Interior Finishing (IF), Steel-Metal (SM) and Mechanical and Electrical (M&E). The region of the survey was DACH and Finland. An emphasis was put on DACH region since they are the focus of the study.

The process is design into four major building blocks which are shown in figure 3. This research design described are formulated to help the process of answering the research questions because this study is represented by different construction trades, so it will allow the researcher to approach all focus groups and gather data at the same time and compare the different findings with each other in a structured way. This is to help get more insight into finding a suitable solution to customers.

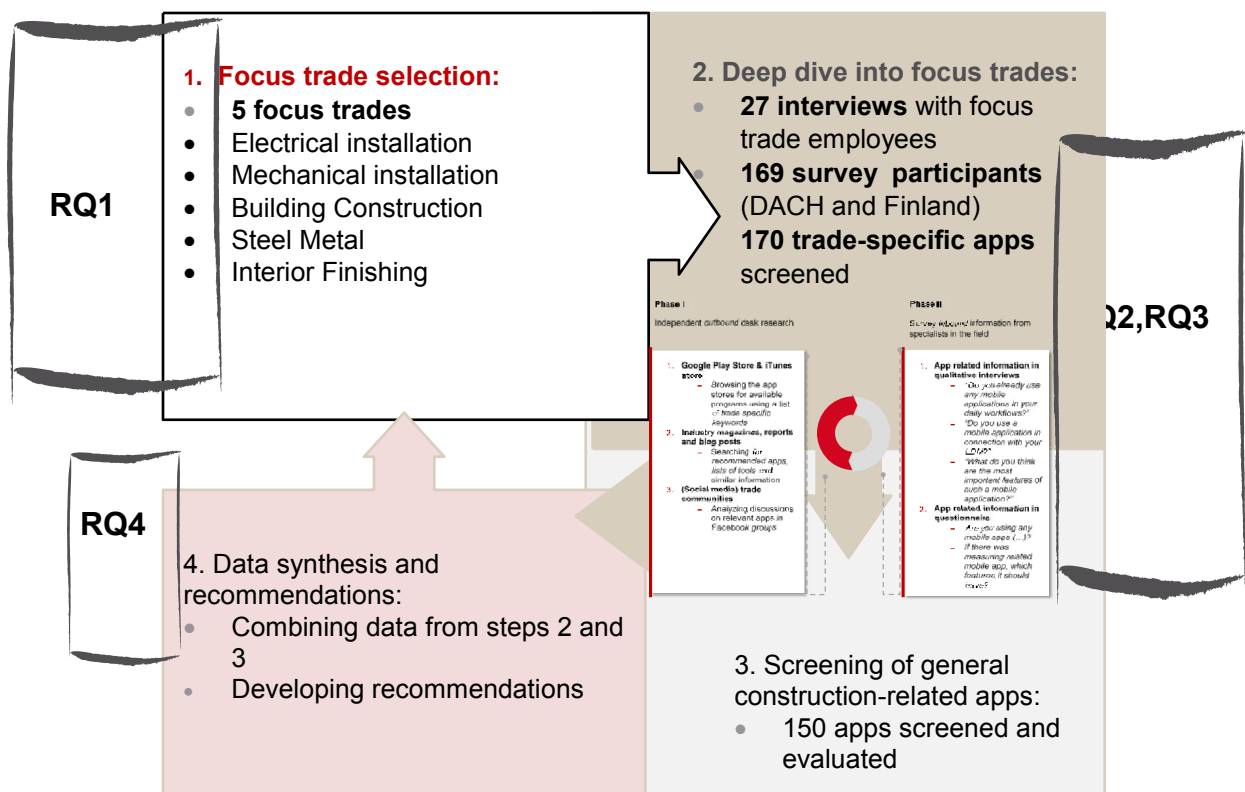


Fig 3: Four building blocks for research design process

3.3 Research process

Based on the research strategy and research design, the research process presented in figure 4 was formulated to answer the research questions and achieve the purpose of the thesis.

The research process is divided into four main phases;

Firstly, the background of the research was analysed to help define and formulate the main concept of the research question. The phases of the research process are to answer the research questions and satisfy the purpose of this research.

In the second phase, literature study from the focus trades was analysed which answers the RQ1. A well-defined scope and assessment framework were created that helped to guide which construction experts to contact and from which market organization of the case company was to be interviewed. This also helped in finding relevant keywords to use in search for suitable literature and journals for further analysis.

In the third phase, the empirical background was presented and interview frame for the data collection was created. Targeted respondents were active community members (e.g. on Facebook) because most construction workers share information on this platform. Participants were mainly foremen and small company owners. Companies with 5 to 500 employees represented, however majority with <100 employees. A qualitative research was conducted to gain more insight into the most relevant mobile app for the case company and to analyse the pain point of customers using mobile apps on construction sites which answers RQ2, and the existing mobile applications (iOS & Android) in the market and their potential for laser distance meter which answers RQ3. Research data was collected to make it easier to cluster and evaluate the most important mobile apps for focus trades in the construction industry, this was to analyse to answer RQ4. Furthermore, a different step in the construction process was considered in the process. Empirical data were collected for analysis to be able to cluster and evaluate the most important mobile application for focus trade in the construction industry for the case company.

Finally, a recommendation was established to see the potential of the research to the case company.

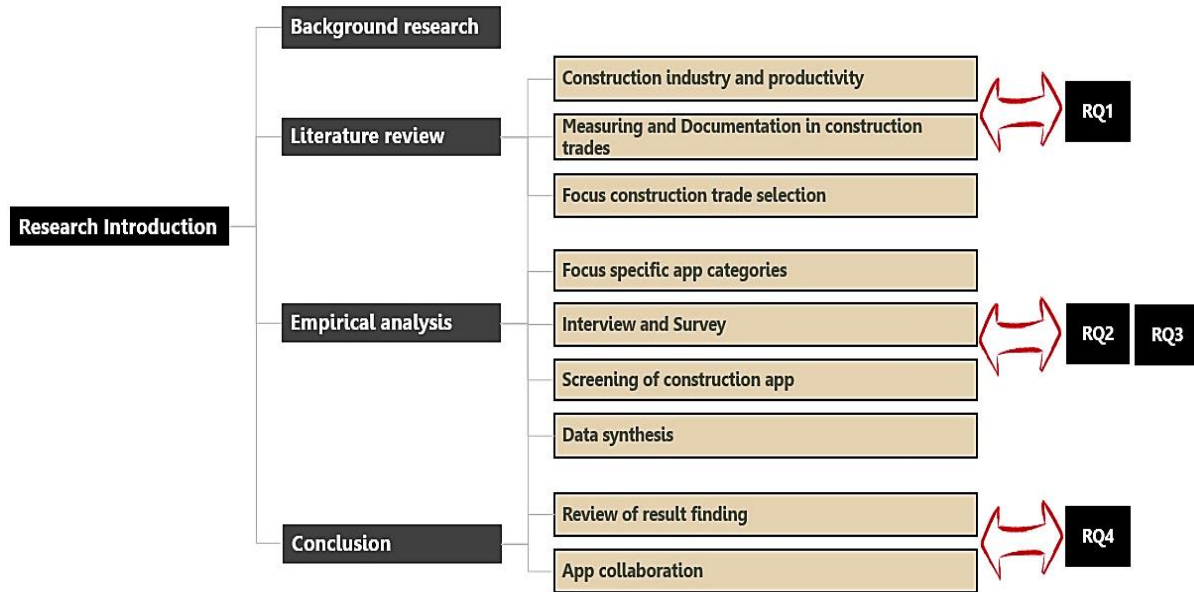


Fig 4: Research process activities and sequence

Further weekly meetings and presentations were conducted for open research questions to validate the process of the research.

3.4 Research method

The following sub-chapter describes the data collection methods used in this study.

3.4.1 Data collection

The data collection used in this research was employing a two-sided independent process to ensure a holistic perspective on available apps. As shown in figure 5, data were collected by using two methods, independent outbound desk research and conducting survey for professionals in the field of construction trades as mentioned earlier in the research design.

This procedure is described by Bryman and Bell (2015) as a narrative method of literature search and claims the method is appropriate for qualitative research with an inductive method, as mentioned before to get a preliminary understanding of the thesis and narrow down the research scope and questions.

Information for the data analysis was gathered from the Social network and knowledge sharing platform and the case company internal websites database, research papers, study materials, Internal Crowd base network.

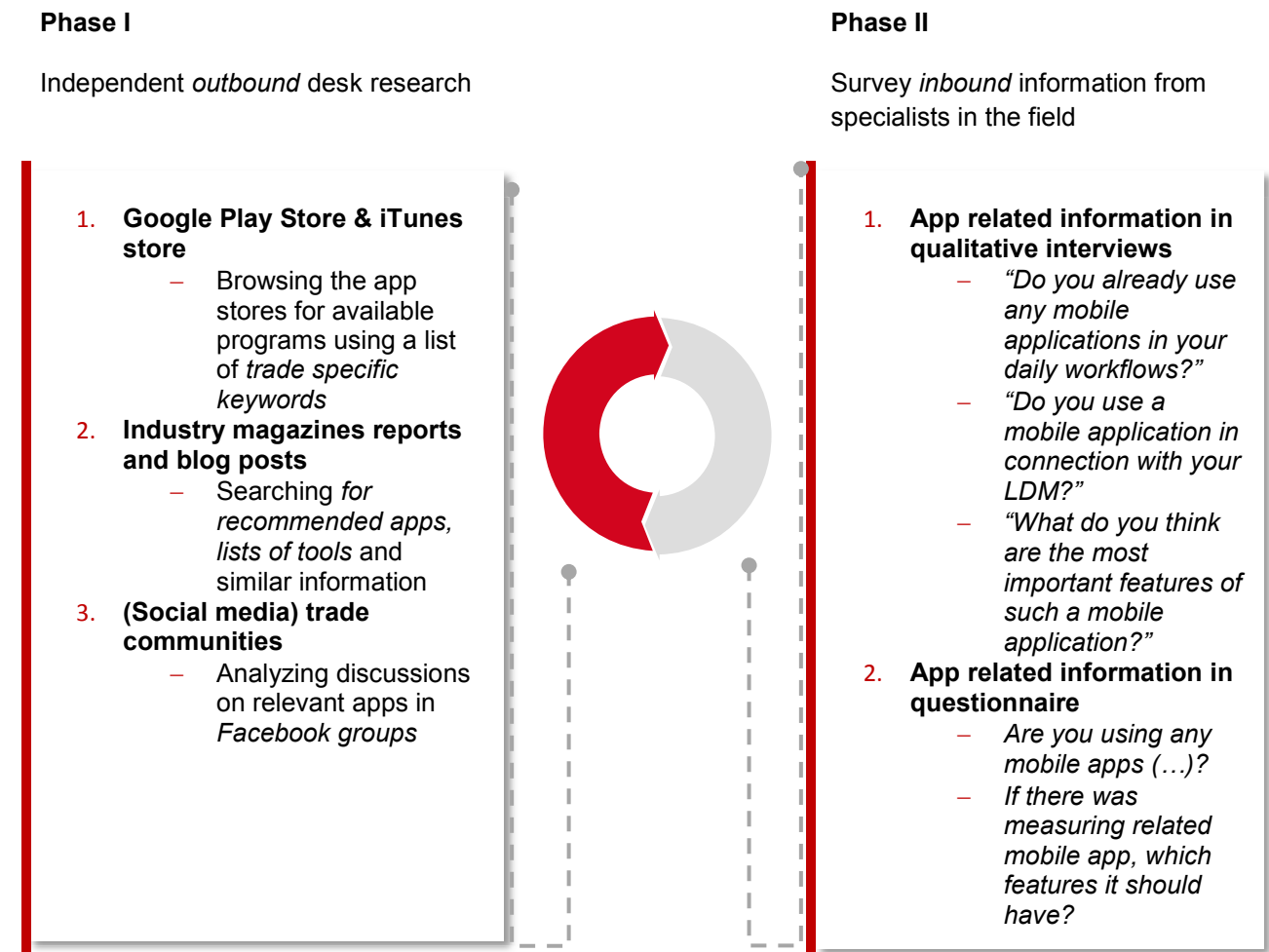


Fig 5: Process for data collection

The rationale behind the independent outbound desk research was to get the desired depth of analysis of various construction trades and apps because of the complexity of the construction market. This also helps to get an initial comprehension of the processes in the construction trades and the most important trade in which laser distance meter is used.

As Bryman and Bell (2015) narrated, Semi-structured interview allows information’s gathering that the researcher did not expect. Therefore, the primary data gathering process used in this study was semi-structured method because it allows the research to make an evaluation between several constructions focus trades described in the research design. It also helps to have a structured format for the researcher to evaluate

the research method. This means that semi-structured interview offers an opportunity to in-depth information gathering and has a significantly structured format which helps to compare, cluster and analysed data in this thesis. (Bryman & Bell 2015).

The research questions were designed to understand the current situations in the construction industry as described earlier in the research design. To be able to answer the research questions, the survey inbound information was divided into two, firstly the app related information in the qualitative interview and secondly app related information in the questionnaire form. The survey was conducted to get information from professional construction workers and an internal survey from managers who have direct contact with the customers in this field.

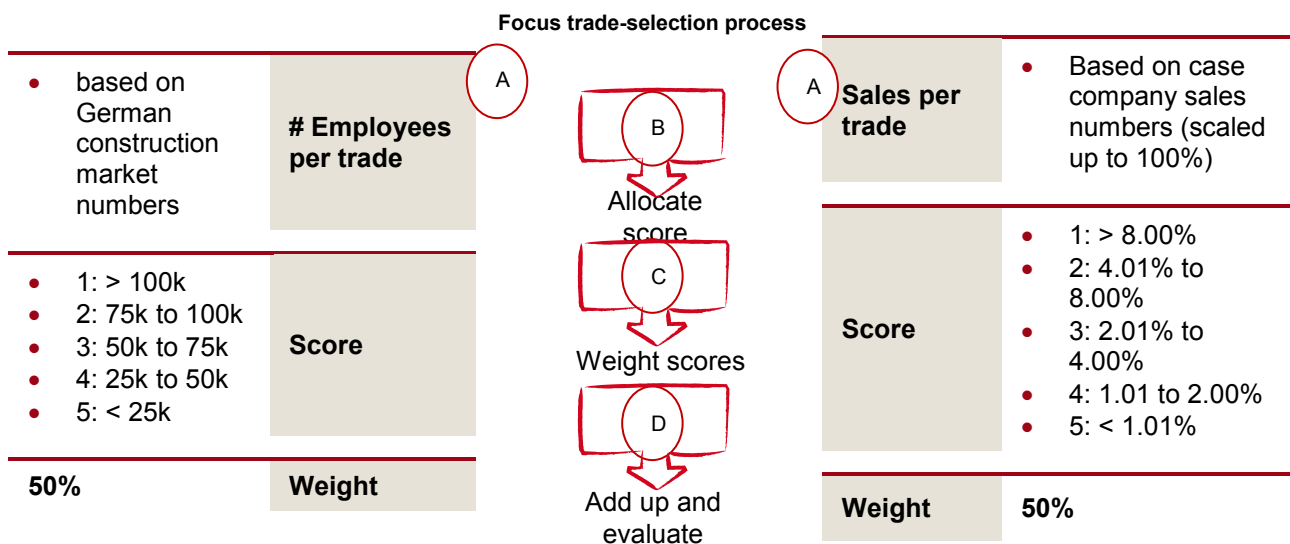
As described earlier, interviews were done with professional construction industry. The interview done between active community and the DACH as described earlier in the research process was combination between self-selected and convenience sample techniques. Self-selected sampling technique is a method which allows individuals to be approached to evaluate if they want to be part of the study or not whereas a convenience sample technique is a method of approaching random people at a convenient place to take part in a study (Saunders *et al.* 2015).

The convenience sampling techniques are thereby utilized by approaching different construction companies and an active community like Facebook, therefore asking them if they want to take part in the study. The self-selected sampling techniques are used in the internal survey with selected product managers and key account managers. As Saunders, Lewis, and Thornhill (2015) described that using an intermediate way of communicating can result to low level of engagement instead of face to face communication. Therefore, as described earlier, self-selection sampling technique helps to mitigate these problems because interviewees and companies selected have interest in the study. The interview was noted by hand with a guided interview form. Analytical method cannot be used since the method of coding for data gathering was not transcribed. This method would have contributed to impartial outcome, but it is time consuming for the study.

3.4.2 Data analysis

The focus trades in the construction industry were scored based on the weight of the data gathered, and analysed on two criteria, the employee per trade and the sales per trade were put into different buckets (k employees, % sales) to which a score from 1 (very attractive) to 5 (not attractive) was allocated as shown in table 3. Since both criteria are important for the case company in terms of current influence and sales potential, a weight of 50% was chosen.

Table 3: Focus trades selected according to number of employees. (Modified from Destatis 2018, Statista 2017, and ZDB 2017).



The overall score was then evaluated, which led to the five focus trades at least one trade per category; construction, interior finishing, installations. The trade 'Concrete Works, Masonry, Restoration' is at the very beginning of a construction process, which is relevant in terms of potential data sharing via an app. Finally, the data is gathered for each construction trade.

4 Measurement relevance on construction trade

This chapter gives the processes in construction trade and answers RQ 1: What is the most relevant measuring/documentation tasks in construction trades?

4.1 Selected construction focus trade

The commencement of any construction project involves measuring, checking, levelling and aligning. As a construction project is accomplished, measurement is essential for checking and documentation process. (Internet of case company, 2018).

Thus, the case company measuring system solution can be used throughout the entire construction phases and can be used for several applications, but the selected focus trades which are Building Construction (BC), Interior Finishing (IF), Steel & Metal (SM) and Mechanical & Electrical Installation (M & E) are the higher sales per shares for the case company. The research is focusing on these trades to add value proposition for its customers, this will make measurements in these trades most efficient, consistent, reliable and accurate to increase their market shares. The rest of the construction trades are equally important to the case company but are not their strongest market in terms of sales per share. (Internet of case company, 2018).

The case company has direct access to its customers in the construction industry in which measuring Systems are one of the businesses that fit perfectly into their customer's application chain. Most of their potential customers in these trades have to layout, measure, align, plumb, document daily and they want to increase their customer engagement and offer efficient solutions by adding value to their products without losing sight. (Fuji & Maru 2010).

Traditional measuring tools still account for approximately 67% of global measuring tool market. These traditional tools include steel tape rulers, spirit (bubble) level, plumb bobs, check lines and builders square. The advantages of the traditional tools are that they are easy to understand and use without any technical knowledge and affordable to purchase. By contrast, the construction laser measuring tool accounts for 13% of the market. Many individuals who could benefit from using these tools are unaware of their availability. (Chrzanowski 1984, Fuji & Maru 2010).

4.1.1 Building construction

Planning is one of the first and the most important steps in building construction process. During this process, a solid plan must be structured to speed up the process of the construction. (Baracco 1987).

Building construction is the operations carried out of collecting materials to form a structure of building. In the construction industry, erecting the reinforced concrete structure, architect planning the phases of the construction project, mechanical systems in the building are very important but measurements are equally important and critical to good construction. (Jackson 1986).

In building construction (BC) ensure that site preparation and elevation is correct where grading and clearing of the site are done to help in the installation of drainage system. Excavation or trenching is done to remove topsoil from the construction site. Measurement need to be done to get an inclined or slope for the graded site that can lead the drainage to its direction. The contractor checks all necessary station points and reference points that are marked to ensure the engineers do their work well. A benchmark is established with reference station in which a centerline is established based on the architectural design. All these can be achieved with the help of correct measurement. As shown in figure 6, there are traditional means of taking measurements at a construction site, some are tape measures, string lines and plumb bobs which are extensively used, but this method is extremely unproductive, subjected to human errors and there are several limitations to it such as functionality versatility. (Baracco 1987, Jackson 1986).

It is also time-consuming and needs two or more people for operation, this can lower productivity and efficiency at the construction site compared to modern laser distance meter. The most convenient way to calculate volume is using a laser distance meter (LDM). Apart from volume calculation, the contractors can also calculate, Direct measurement, Area, Indirect measurement (Vertical, horizontal) Pythagoras, Trapezoid Special, Continuous measurement, Delta. (Chien *et al.* 2003).



Fig 6: Comparison of traditional method and laser distance measurement (Internet of case company 2018)

Preparation of pouring concrete

The most important step to deliberate when preparing a concrete mix is to determine the constituents that can be used and their quantity. There are lots of things to consider during this process which laser distance meter (LDM) play a crucial role including the type of cement, aggregate size and type, amount of water to be used, and mineral and chemical admixtures. (Thomas *et al.* 1986).

The composition of cement makes up only about 15% of the concrete by weight (11% by volume), with the remaining making up the aggregate and water. It is very important to combine about 1-8% amount of air or a chemical called air entrained to increase the capacity of hardness and resist damage during unfavorable weather condition. These estimations can be easily done by using laser distance meter to achieve a successful measurement. (Thomas & Jennings 2018).

The motive for the job is to create a smooth concrete surface, at the right height from the reference benchmark and the horizontally levelled across the entire area. Concrete pouring is a horizontal measuring application with a good mix design, it can still result in poor-quality if it is not implemented appropriately, a bad mix design will of course always give poor results and If it is not levelled correctly, it may have to be removed, polished or redone, this causes waste of resource and can be avoided by using laser distance meter. This is going to cause low productivity due to the waste of time and resources. Figure 7 shows a building construction site with the uniform concrete mix. (Thomas & Jennings 2018, Thomas *et al.* 1986).



Fig 7: Building construction site permitted from pixabay (Akyurt 2018)

Concrete workflow

Concrete works are important part of almost any construction process; these are the typical steps during any concrete installation work done at the construction site. (Jackson 1986).

Designing the concrete mix is a very important step for attaining a good final as seen in figure 8. This is done to have an evenly distributed fine aggregate cement paste which shows that large air compact is removed and fully saturated in water.

As the process is shown in figure 9 below, once the concrete has been adequately mixed, it is poured into a form, filled with either wire mesh or rebar to define its shape and position. Both components add structural integrity to the building. Rebar is used for high load bearing surfaces. Wire mesh could be used too but does not offer the same structural integrity. There is the possibility of segregation if the concrete flows too quickly into the formwork. (Thomas & Jennings 2018).

To make sure all corners of the formwork flow with concrete, it is very important to consolidate the removal of large particles of air, this process is called compact. It is critical that the formwork is levelled and aligned properly when installed, to avoid any defects, this can be very costly. (Thomas *et al.* 1986).

Forming has two measuring tasks which are vertical aligning and horizontal levelling. The traditional way to check this is by using a spirit level or a plumb bob to take the measurement which can cause much defects and errors. Final handling of the concrete

surface is done to achieve the desired properties. This is done by smoothing the surface when the concrete is about hardening. The concrete must be allowed to cure at the desired rate to have a fine property. Curing is done to harden and strengthen the concrete which helps it to become less susceptible to cracks and stress. (Jackson 1986, Thomas *et al.*1986).



Fig 8: Concrete mix and levelling process (Ratnikov n.d.)

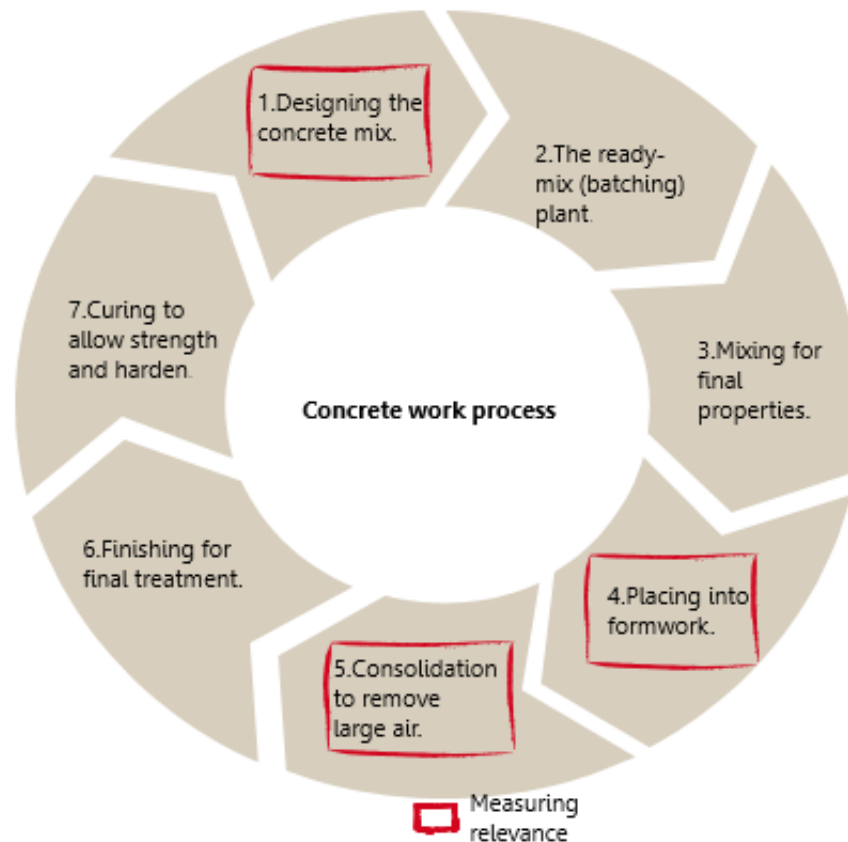


Fig 9: Concrete mix work process and measuring relevance (modified from Thomas & Jennings 2018).

Relevance for measuring

These show the relevance of using laser distance meter in building and construction trade to achieve a successful work with a higher productivity level. (Thomas & Jennings 2018).

- Footings, columns, walls etc. must be measured and documented to the drawings
- Levelling and Aligning of formwork
- Volume calculation for concrete pour
- Drawings used for ordering and pricing
- While placing concrete the thickness and width needs to be measured
- During vibration compacting process radius of vibration needs to be measured.

4.1.2 Interior Finishing

Interior Finishing is the process in construction trade which protects the surface layer of building a component from any hazardous weather condition and fire. One advantage of interior finishing is to fix scratches on the surface of the building. It is also important to coat the surface of the wall, floor and ceiling for a suitable appearance and to protect the construction from effects such as water, heat, moisture, abrasion. (Mudarri & Fisk 2007).

During the early stage of civilization, traditional building methods were used to provide shelter and prevent harsh weather condition. Materials used during those early days are adobe, stones and wood such as the Pyramid of Egypt. In this modern era innovation and technology has transitioned in providing buildings with more comfortable installation for interior finish. (Riggs 2003).

There are three main components of measurements which are level of measurement, dimension and uncertainty. Walls are used to distinct spaces from each other vertically in interior finishing but depending on the structural system of the construction it may also transmit some force. Erected walls must protect the space against any natural phenomenon that might occur in the building such as the effects of water, moisture, heat, noise, light and fire. The section in the wall can be analyzed in three layers; interior coating, core and exterior coating while others can be formed by one layer. (Riggs 2003).

To protect properties, comfort condition and safety of users, finishing materials must have an adequate compressive strength to resist to physical effects. It must guarantee enough insulation properties and be nonflammable. (Mine *et al.*2014). Figure 10 shows how interior finishing looks like.



Fig 10: Interior Finishing permitted from pixabay (Dagmara n.d.)

Installation of suspended ceiling workflow

Suspended ceilings are mounted to lower a ceiling or create a hollow space for the installation of lighting, plumbing, wiring and ventilation systems. In the DACH area, suspended ceilings are usually offered by plasterers and dry masons. Installing suspended ceiling achieve basically three main requirements which are the appearance of the mounted ceiling, the main purpose of the suspended ceiling and the structural firmness of the suspended ceiling. (Miller *et al.* 2004, Villaverde 1997).

These three requirements can only be achieved when there are a proper guide and safety regulations for installing the suspended ceiling. As shown in figure 11, it is often very important to use qualified engineers who have technical knowledge and techniques with the right material for the job.

Installing suspended ceiling is one key application in an Interior Finishing. Suspended ceiling offers two advantages over a permanent ceiling.

- Dust, pipe and cables hidden above the suspended ceiling are easily accessible in case of repair or modification.
- Suspended ceiling provides better sound barriers than permanent (drywall) ceiling.

There is also a raised floor system which contains load-bearing floor panels placed in a horizontal grid which is reinforced by adjustable vertical bases to provide an under-floor space for the housing and distribution of service. This floor panels can be removed to permit rapid access to the under-floor service. There are three traditional methods for

horizontal levelling when installing suspended ceiling which are Spirit level, Tape measure, Chalk line. (AAAMSA 2007, BCA 2010).

Position of the wall is marked with chalk line together with a spirit level and tape measure for the right position to raised floor and suspended ceiling. For fast and accurate measurement, laser distance meter is required for ceiling and floor application.

As the working process and measuring relevance presented in figure 12 below, first and foremost the vertical ceiling drop is determining by measuring the dimension of the room. This is followed by installing the upper ceiling grid and vertical drop tees with the desired height. Set up the lower angle piece parallel to the reference wall and mount the floor track along the point. Finally install ceiling tiles into vertical drop accordingly. (AAAMSA 2007, Miller *et al.* 2004, Villaverde 1997).



Fig 11: Traditional method and laser distance comparison permitted from pixabay (Liszewski 2011, Vanessa 2018)

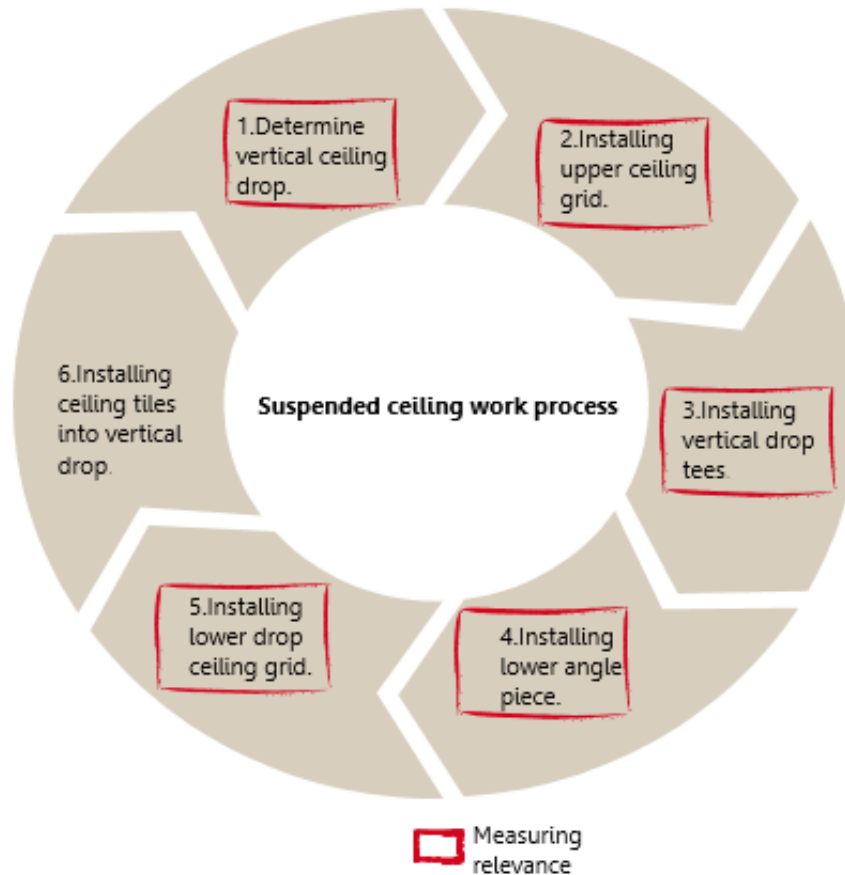


Fig 12: *Suspended ceiling work process and measuring relevance (modified from AAAMSA 2007).*

Relevance for measuring

The relevance of measuring in suspended ceiling is very important for accurate installation; this can only be achieved by using laser distance meter. (BCA 2010).

- Measuring room dimensions and position for mounting vertical ceiling
- Positioning the upper ceiling grid need some measurement
- Installing the vertical drop tees and the lower angle piece for structural stiffness
- Positioning base and carrying battens so that the ceiling is even and in balance
- Final measures of the worked area for the calculation of actual construction costs.

Installation of drywall workflow

There are different construction techniques for installing drywalls, but the procedure and stages of the workflow are usually common on the construction site. Drywall construction includes setting out the building and finishing of lightweight construction walls, that either separate rooms or create a hollow space for the installation of electrical, sanitary or heating systems. Drywall installation needs a solid foundation that would hold paint or wallpaper. The material for the foundation is more expensive and takes longer to build for that reason, it is very important to consider the safety and health of workers and follow the right procedure to achieve a good drywall installation as shown in figure 13 below. (BCA 2002, BCA 2010).

Drywall construction is an important part of Interior finish trade which is also known as sheetrock, rock or wallboard as seen in figure 14. Firstly, lay out the position for the drywall for cutting and tracks into which the gypsum board will be mounted later. Secondly, mount the drywall track by gluing and screwing with a direct Fastening tool. Thirdly, mudding and taping the drywall onto the tracks, making sure that they are vertically aligned, to achieve this you need a tool which can measure and give an accurate result. The drywall typically comes in sheets of different sizes. (BCA 2002).



Fig 13: Drywall installation permitted from pixabay (GmbH n.d, Shutterstock.com n.d.)

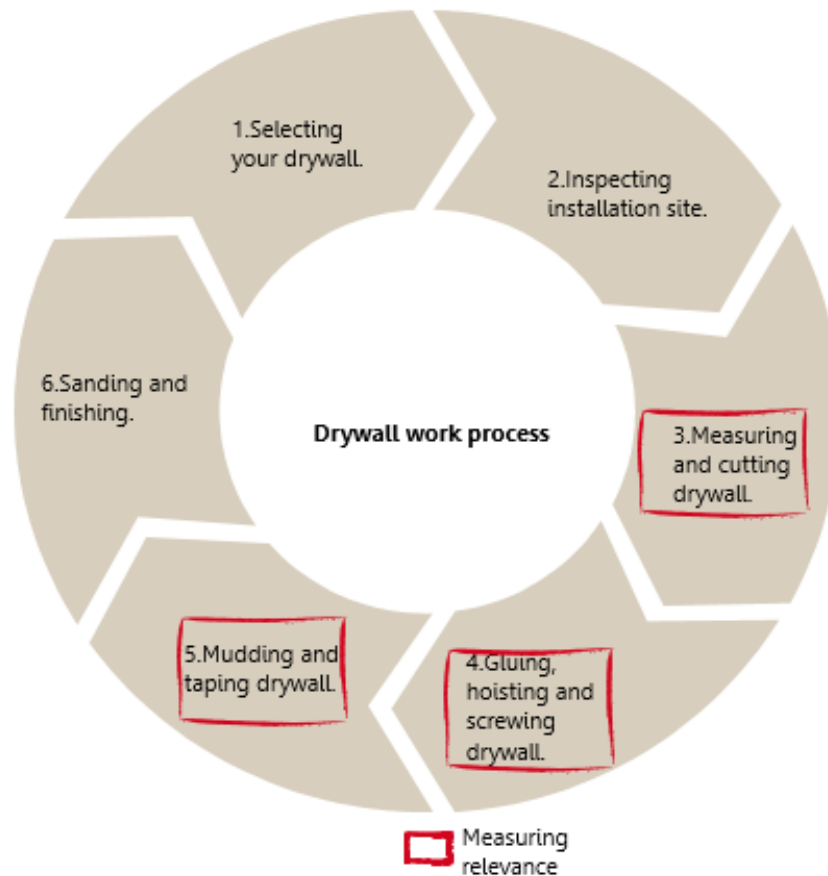


Fig 14: Drywall work process and measuring relevance (modified from BCA 2002)

Relevance for measuring

Measuring is an important part in the construction of drywalls and suspended ceiling before and after the finishing phase of the construction process. Laser distance meter are widely used in this trade because it is convenient, fast and reliable. (BCA 2002).

- Measuring room dimensions and position
- Calculation of volumes length, depths and heights. Use the data to calculate for area and volume.
- Positioning for gluing and screwing with laser distance meter.
- Final measures of the worked area for the calculation of actual construction cost.

4.1.3 Steel-Metal

A structure is a design with the composition of structural steel to be able to withstand the weight and any stress for adequate firmness. Structural steel and metal are one of the most reliable materials in the construction industry which require less material than other types of structures. One of the main disadvantages of the steel structure is susceptible to corrosion, which requires that protective measures must be taken to ensure that it does not corrode. In modern building applications, steel structures have become very versatile and are used for supporting members in buildings and larger structures that vary widely in purpose and design. (Liew 2001, Miller *et al.* 2004).

In the construction industry, architects, contractors, engineers and designers prefer structural steel over any other metal because of its advantageous, it can be combined with other building construction materials that have high elasticity limit, durability and easy to weld. It should be noted that, structural steel can be used as a multipurpose product. Not only that but it is affordable, easy to acquire and safe, its properties such as high-strength and versatility make the entire life cycle of a construction building environmentally friendly because it can be recycled. (Gaylord & Gaylord 1957).

Steel and metal are an exterior trade involving several measuring tasks. The three key applications are erecting steel structure, Decking and Façade. Steel structures require a high degree of precision. Columns and beams are prefabricated and leave only minimal tolerances on the construction site. Usually, cast-in bolts are used to fasten the columns onto the floor. (BCA 2017).

Steel structure

Steel components are assembled into a frame so that they can be erected at structural steelwork. This procedure includes carrying and placing structural components into their positions then connecting them together. This reinforcement is done to add more strength and stiffness to concrete in building construction. The assembled frame needs to be horizontally levelled and vertically aligned before bolting up is completed. (Liew 2001).

Steel erection is often the skeletal core of bridges, offices buildings, commercial, retail and industrial structures as it can be seen in figure 15. Steel is used over centuries in construction because of its thermal expansion coefficient which is like that of concrete and seen as the supreme since its flexibility and versatility means engineers, designers, and architects can use it in numerous ways to achieve a purpose. (BCA 2017, Liew 2001).



Fig 15: Steel metal work permitted from pixabay (Bannafarsai n.d, BCA 2010)

Before the structure can be connected there is relevance for measuring to each of the reinforcement joint, bolted or welded columns which are a vertical element need to be vertically aligned to be a perfect stiffness. The beams which are the horizontal elements need to be horizontally level. All these alignments can be achieved by using a laser distance meter to get a perfect measurement for the connection. (BCA 2017, Gaylord & Gaylord 1957, Liew 2001).

Decking workflow

When the steel structure is erected you can start installing the decking. Decking is not only the final roof on top of the building. It also appears between levels. In this case decking is installed and concrete is poured on top of it. It is the responsibility of the structural engineer to choose the decking and its preparation. The Structural engineer must consider the type of slab which must resist an applied force and anything which can cause danger to the health and safety of people. (BCA 2010, Liew 2001).

The workflow of decking start by measuring and planning the deck holes for the post as shown in figure 17 and it is measuring relevance. After having the layout measurement, concrete is poured, and anchors are placed with the right measured angles. To attach the beam to the anchors you need to check the alignment of the beam and the rim joint, and also measure inclination to add fasteners to the joints. All these processes need some measurement of horizontal levelling as well as slope to install the deck. (Rackham, Couchman & Hicks 2009).

There are two main structural functions available during concrete work, which are the support of wet concrete and strengthening by decking with the help of the slab in the construction process. It also helps to support the concrete weight on the floor. One important thing about decking is the ability to support torsional buckling during

construction process and serve as a buffer to transfer forces across the walls and the columns of the construction building. (Rackham, Couchman & Hicks 2009).

By using traditional measuring method, you need nails, string line, bubble level and tape measure as seen in figure 16 below. Laser distance meter is used to measure lengths, offsets, spacing, billing, quotation and for the calculation of areas and storage of dimensions.



Fig 16: Decking example permitted from pixabay (Atlas-Machinery Ltd n.d, Indypendenz, n.d)

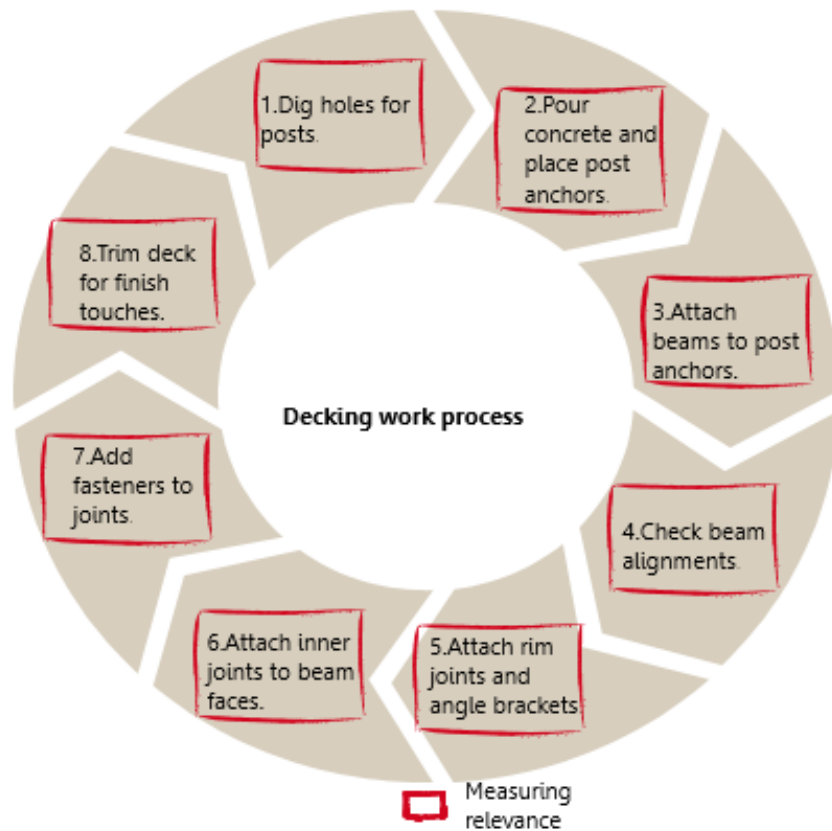


Fig 17: Decking work process and measuring relevance (modified from Liew 2001)

Relevance for measuring

The measuring process and planning of decking start by digging holes for the post which need laser distance meter (LDM) to measure lengths, offsets, spacing, billing, quotation and for the calculation of areas and storage of dimensions. (BCA 2010, Liew 2001).

- Layout measurement is done to serve as a guideline for post.
- Form from timbers is measured to ensure symmetry.
- Measure inclination to avoid imbalance of decking.
- Measurement is done to determine the place of drilling holes to attach brackets and beams.

Roofing workflow

The roof is a structure which is used to cover the upper of a building and serve as a protection against any natural phenomenon and help in the security and privacy of a person and it is also one of the essential elements of the building.

There are different types of the constructed roof which are made from different types of materials, some of which are, flat roof, sloping roof, vaulted and domed. The use of structural steel and concrete in the construction industry made Flat roofs one of the most popular roof usages in Europe and America. Structural steel and concrete have been widely replaced from a truss which is a structural framework made of wooden beam composed of a series of triangles lying in a single plane. (Liew 2001).

It is very important to consider all technical limitations before choosing the roofing material. All kinds of roofing have benefits and their setbacks. It is certain that deciding on the type of roofing is one of the critical decisions when designing a building. (Radziszewska-Zielina 2014).

Roofing is generally an exterior type of a building which is usually there to protect the structure of the building against perspiration and harsh weather. The truss which makes the structural framework of the building is mounted. One of the most important aspects from a design standpoint is to set the layout to determine the place for the screw and braces for the end truss. The roof sheath is a set which determine the tone for the rest of the building, as shown in figure 18 install the drip edge and underlayment. The area of roof cover is measured by the width and the building length. (Kreith & Goswami 2005).

The productive way of solving this application steps is by using laser distance meter for accurate measurements and for alignments. String line and plumb bob is the traditional method for aligning roof. The method is unproductive, it requires two or more people, and it's vastly time-consuming and far less accurate, compared to modern laser method. (Radziszewska-Zielina 2014).

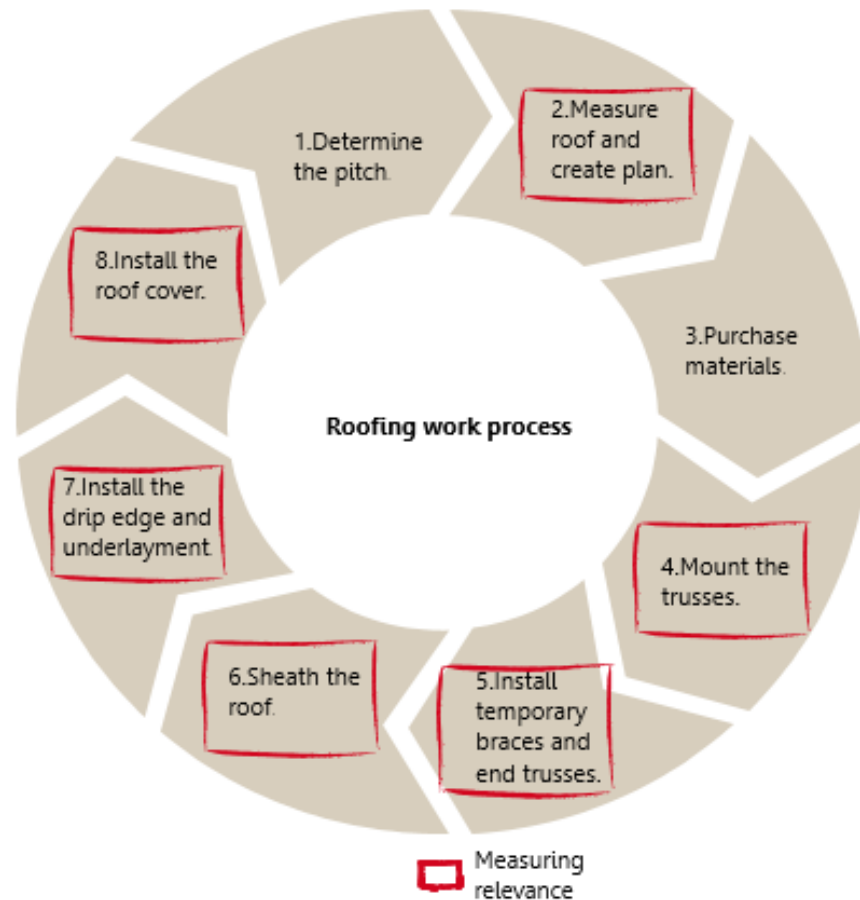


Fig 18: Roofing work process and measuring relevance (modified from Kreith & Goswami 2005)

Relevance for measuring

From the engineering perspective the roofing is also of great importance due to its impact on energy efficiency which makes measuring accuracy important to avoid energy loss in a building. (Kreith & Goswami 2005).

- Measuring and documenting roof area for material orders
- Measure inclination to mount the truss
- Layout measuring to determine the place of screws and right size of materials placed
- Measuring the angle of a cut to install drip edge and underlayment
- Roof cover must be measured before installing.

4.1.4 Mechanical & Electrical Installations

Mechanical and Electrical (M&E) installation is an interior trade which is very important in the construction industry and has several measuring tasks. These trades consist of numerous professional expertise, which is made up of three- key applications such as the installation of pipes, installation of HVAC (Heating, ventilation, air-condition) and cable tray. The mechanical and Electrical design is based on an architectural plan of the construction, which need a qualified engineer to read and comprehend the optimization of material required for installation to achieve a high performance. (Hasan *et al.* 2013).

Mechanical installation workflow

Mechanical installations refer to mechanical systems design for implementation and maintenance of sanitary, heating and air conditioning construction tasks. Typical projects of mechanical systems are used in heating systems or sanitary facilities and industrial building; it can be seen in figure 19 below. There are three key applications in a mechanical installation which are air-conditioning, mechanical ventilation and space heating. (Carnes 2005).

Mechanical ventilation is the process of ensuring the free flow of air circulation in a building to keep pollution as low and as safe as possible. Air-conditioning is to keep the temperature in the building and humidity at optimal for good health. When there is low humidity it can cause skin diseases while high humidity can also cause the growth of bacteria's, moulds and fungus in the building. (Carnes 2005, Kreith & Goswami 2005).

Conditions at the construction site need to be assessed for a reliable planning of the project to commence. The mechanical engineer measures distance to get the right size for installing of HVAC correctly because it is an important part of a residential structures such large industrial and office buildings. This includes laying out ideal paths for the heat circulation throughout the system-e.g. from the gas inflow to the heater placement to design a system of pipes or steam piping. (Hasan *et al.* 2013).



Fig 19: Mechanical installation permitted from pixabay (Xmentoys n.d, infrastructure B. et al. 1995)

Measuring task required to install HVAC primarily need to apply levelling and aligning (horizontal and vertical) measuring tasks which can be followed in figure 20. It is therefore very important creating a map of the system that can help in the installation of pipes and radiators. (Korman *et al.* 2010).

This is achieved by defining the volume of the room. Depending on the use case different materials can be used for the pipe installation it can carry water, natural gas and waste out of the building. Space between radiators a measured so that pipes are layed from radiators and faucet to the boiler. Laser distance meter is needed for correct and accurate measurement of pipes as well as to estimate the room volume where the HVAC system will be installed. The room volume is needed to pick the right system. (Carnes 2005).

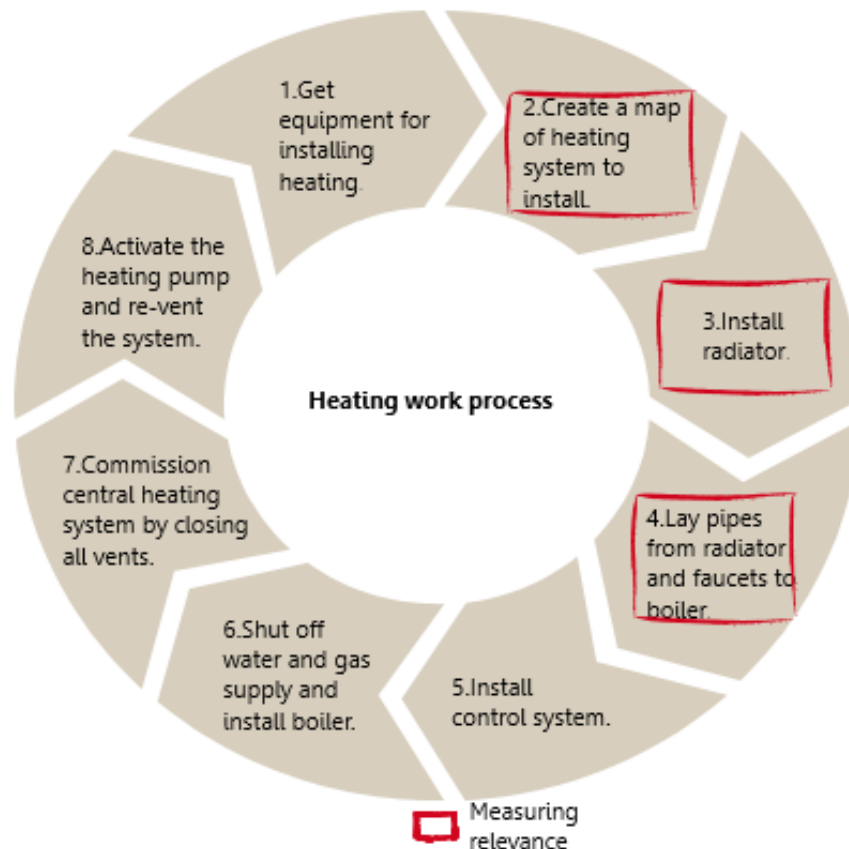


Fig 20: Heating working process and measuring relevance (modified from Korman et al. 2010)

Relevance for measuring

It is very important to make sure harmful combustion products are removed by having a well-secured vent. HVAC is the technology of indoor and provide environmental comfort. (Korman et al. 2010).

- When building the pipe system at the construction site, pipes need to be cut to their right lengths based on measurements
- Laying of the pipes need some measurement to be able to have the right levelling for installing the pipes.
- The volume of the room needs to be calculated to be able to know the right size of radiator to be installed.
- Transfer layout from floor to ceiling is measured.

Electrical installation workflow

Electrical installation is the design, selection, installation, maintenance, and repair of (electrical) systems in the context of commercial, residential, agricultural, or industrial shell construction, new construction or renovation projects. The trade includes professions such as electrician and one of the main challenges in electrical design is defining the optimal routes for conduit and wiring. (Korman *et al.* 2010).

Electrical installation systems are much more flexible than Mechanical installation systems because electrical circuits require much less space for an optimal routing. With the aid of laser distance measurement device, circuit and wiring can be positioned without struggling to find space for mechanical and plumbing installations. (Carnes 2005, Hasan *et al.* 2013).

The electrical installation process requires a cable tray system which supports insulated electric cable used for power distribution and communication in buildings as shown in figure 21 below. The electrical load, current and cable size are calculated. Cable trays are used as a substitute to an open wiring. They are suitable in a situation where changes to a wiring system are anticipated, as new cables can be installed by laying them in the tray, instead of pulling them through a pipe. (Korman *et al.* 2010).

Several types of the tray are used in different applications. Cable trough or cable channels are solid cover used on cables. A solid bottom tray provides the maximum protection to cables but requires cutting the tray or using a fitting to enter or exit cables. An integrated MEP engineering method results in a better fulfillment than laying down each building system in isolation when it comes to designing systems. Interactions between building systems can be especially difficult to coordinate when the design process is isolated, and equipment location conflicts are very likely. As shown in figure 22, the outer insulation of a conductor is selected. (Korman *et al.* 2010).



Fig 21: Electrical installation, traditional method with laser distance meter permitted from pixabay (Kalinovsky n.d, Lazada.com.ph n.d.)

To install cable trays, you would primarily need horizontal levelling and vertical aligning but also distance measuring. Laser distance meter can be used to measure the required length of cable trays. Estimating the material need, the productivity benefit using a laser meter over traditional method becomes greater with increasing distance. Laser distance meter can be used to measure the required length of cable trays. (Michael 2018).

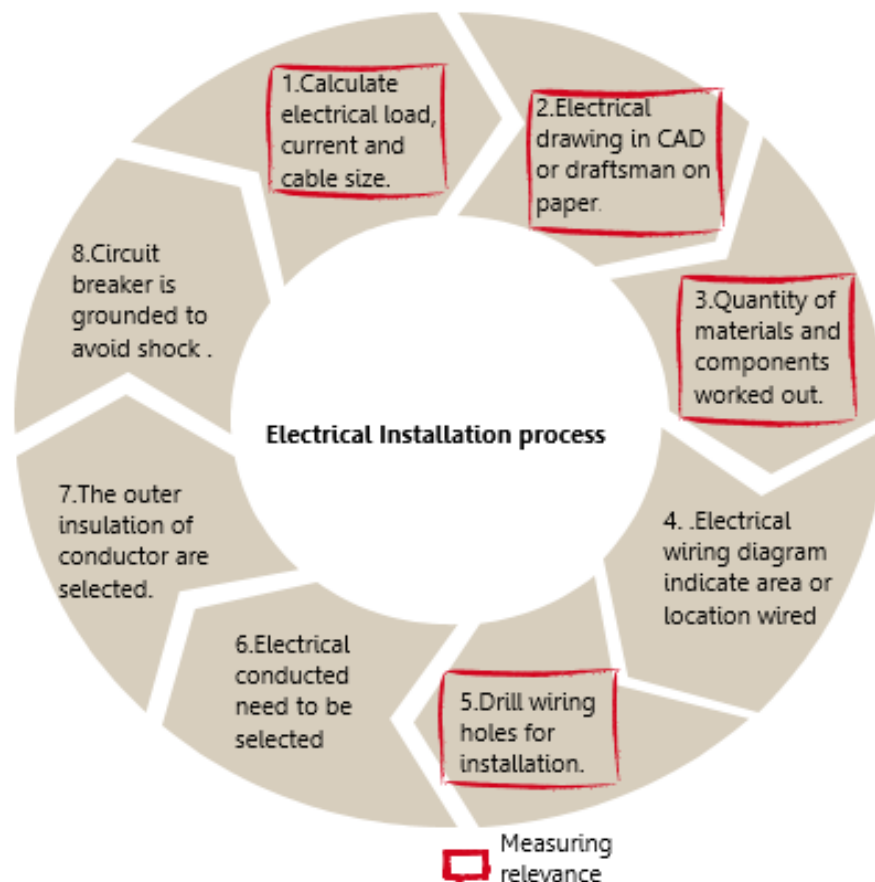


Fig 22: Electrical installation workflow and measuring relevance (Modified from Korman et al. 2010)

Relevance for measuring

While mechanical engineers need to calculate heating and cooling loads to estimate the volume of equipment needed, electrical engineers design electrical circuits and define a defense mechanism measures to allow equipment to function safely without any interruption. (Korman et al. 2010).

- Double check measures of architectural plans or the CAD drawing

- Determine the location of installation to be measured for drilling of holes for installation
- Material estimation is needed to know the quantity of component required
- Lengths of cable or cable tray are measured.

4.2 Case company overview and background

This chapter describes the current state of the case company and the process in which the thesis was conducted.

4.2.1 Overview of case company current state

The case company develops and produces products and services with top notch technology mainly for professionals in the construction and energy industry.

The case company portfolio contains seven business units. Among these seven-business unit is the Measuring systems where measuring devices such as distance laser, radar and optical tools are used to support construction professionals during the phases of their work by measuring and laying out foundations, aligning and leveling to have a uniform measurement.

The company distance laser portfolio is categorized into entry level, mid-range and high End. The sales for the mainstream distance laser are growing in which its main strategy is simplicity approach and design focus as the key success factors. The high-end distance laser sales forecast significantly reduced due to the changing trend in the construction industry where everything is now moving towards digitalization. The case company aims to initiate a step to make their existing customers lives easier by the introduction of a construction-related mobile application which will help the case company increase it sales margin for the high-end distance laser and ensure balanced and healthy portfolio with growth potential. This strategy is to sustain value creation through market leadership and to create loyalty and long-term relationship with customers.

The company's current state and background is a concern to management board and the stakeholder. Their concerns include how to increase customer engagement by adding value to the high-end distance meters. With the current market trend of (Bluetooth) connectivity to external apps & softwares there is an opportunity to define

trade or application relevant apps which increase the trade-penetration of the case company portfolio. This will help the user to quickly transfer measurements details directly to 3rd party apps.

4.2.2 Case company background and research process

The process of the research was done and compiled inside the case company between the month of March and August 2018, where a presentation was done to the executive board of the company. Relevant Information was gathered by weekly meeting with the management team that might be needed in the progress of the research.

There were management meetings to gather information about the current situation in the market, the background of local market organizations and further development processes that can help bridge the gap between competitors. The research was more of practical orientated where the management team want to see most of their concern being addressed and results been met.

Information were gathered from the case company intranet such as business processes, sales channel for each trade, current practices and processes, for that reason management decided the name of the company should not to mentioned in this research. After gaining an insight in the case company's product portfolio for distance measuring business and having an in-depth understanding of the sales channels, focused trades and trade specific application of distance measuring tools, market reach and training capacities, an onboarding process of the research construction began.

The recommendation given was relevant to the core structure and objectives of the case company which is quality, innovation, easy to use system solution, adaptability and direct customer relationship.

It can be concluded that measurements are critical to good construction, which is required from the beginning to the final completion in all construction trades

5 Result and Evaluation

This chapter describes the results and analysis of this research and to answer the RQ 2 and RQ 3.

5.1 Key construction related apps categories

Today's differentiation of laser distance meter tools is mainly based only on the interior or exterior applications. With the current market trend of Bluetooth connectivity to external apps and software's, there is a great opportunity to define trades applications relevant to integrate laser distance meter, this will increase the penetration capacity of laser distance meter into the mainstream market. (Morgan 2009).

About 150 construction apps were screened and categorized into various features shown in table 4. The apps are categorized based on their functionality and these are project management, measuring, design and visualization, estimation, billing and quotation.

Table 4: Clustered app categories and its features

App Categories	Features
Project Management	Task- and issue management, documentation, annotation, data exchange, time tracking, etc.
Measuring, Design & Visualisation	Non-CAD/BIM floorplans, visualization of products, measuring apps, etc
Quotation, Estimation & Billing	Creating tenders and bills, estimate material usage and costs, etc.
Computer Aided Design (CAD)	Design, documentation, 2D drawings, 3D models, etc
Building Information Modelling (BIM)	Design, documentation, 3D models with single component details, project management, collaboration and data sharing, etc.

An example of how the features of an app were analyzed to determine its category is shown below in figure 23. Firstly, a construction mobile app is selected, and its features are analyzed to see in which category it can be grouped.

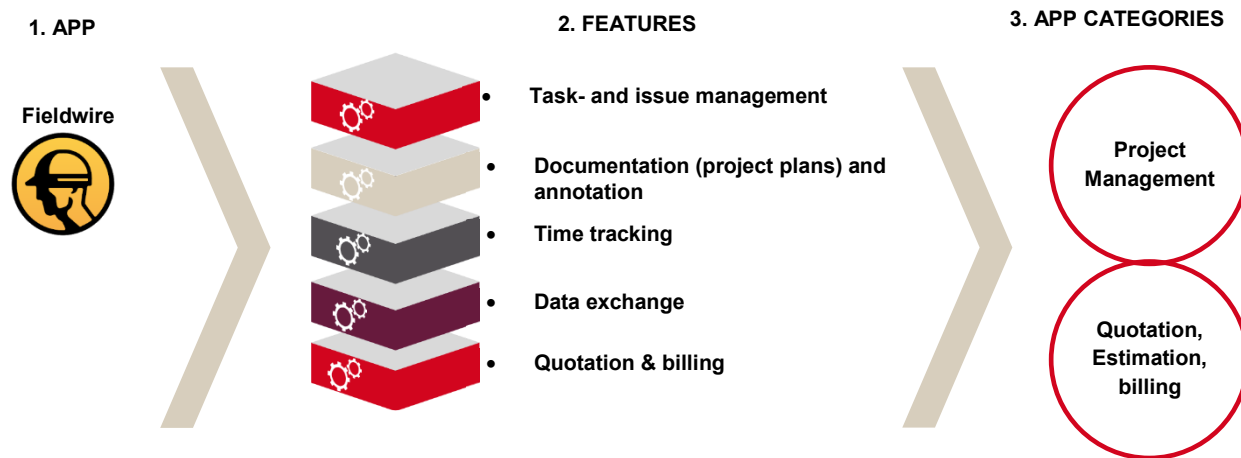


Fig 23: Example of how apps were analyzed in its category

Construction apps for construction professional are usually based on project management tools. Project management is one of the most important construction-related app categories. These tools help the construction worker to share and markup 2D and 3D files on the construction site and in the office. Instant communication of project information and real-time data sharing is very important in the construction industry. Plan viewing, reporting daily duties and schedule, punch list is one of the transformation apps in the construction business. The outcome of implementing mobile technology in the construction industry will continue to grow and expand, this will help increase the use of laser distance meter if proper training is given to the construction worker, not only will that increase the use of laser distance meter but also make their work easier and more productive. (Abaffy 2011, Venkatraman & Yoong 2009).

5.2 Insight of LDM usage by respondents

Five construction trades were selected to be analyzed and evaluated to answer RQ1, among which at least one trade per category was selected based on the highest sales per shares for the case company. Since construction process phase is started by concrete works or masonry and restoration workers, they were the first construction trade to be contacted

To evaluate the construction mobile applications, the questionnaire responses were transformed by the weight to each factor of the respondent, ranging from 1 to 5 in which “1” is very attractive and “5” not attractive as indicated in the data analysis; the highest weight in this study is 50%. Example is illustrated in figure 24 below.

Evaluation	1	1	3	4	5		
Trade	Electrical installation	Mechanical installation	Building Construction	Steel Metal	Interior Finishing		
Trade	# Employees	Score	Weighted (50%)	Sales (100%)	Score	Weighted (50%)	Overall score
Electrical Installation	159,000	1	0.5	11.28%	1	0.5	1

Fig 24: Example of construction trade evaluation demand

Participants were mainly foremen and small company owners with majority having less than 100 employees as described in the previous chapter. It is estimated that almost half of the construction trades 53 % out of 161 respondents as shown in figure 25, use LDM in their daily work interior finishing trade which is about 96% out of 161 respondents has the strongest focus on measuring and LDM usage. Building Construction professionals are the next construction trade after Interior Finishing which is about 64% out of 161 respondents that uses LDM in their daily work.

Low usage of laser distance meter leads to limited offering of measuring-related apps especially in Mechanical installation which make up of 35% out of 161 respondents. Wide LDM Usage combined with Data Transfer challenges leads to great potential for mobile apps. Majority of construction workers uses LDMs in their daily work, some of the prominent LDM they use are Hilti, Bosch and Leica.

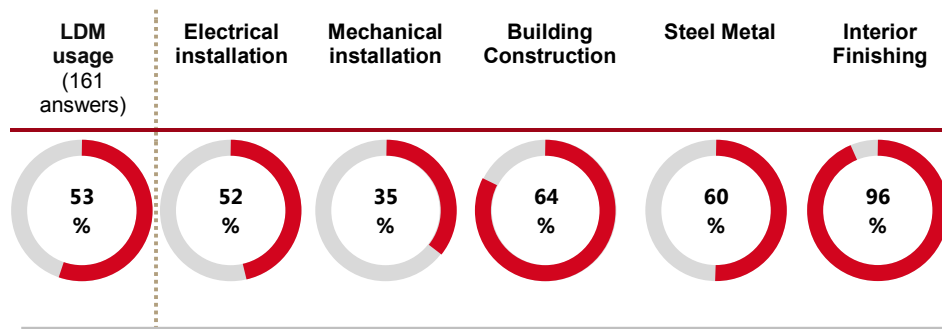


Fig 25: Insight of Laser distance meter (LDM) usage by respondents

Documentation and data sharing are very important in the construction industry. Most construction work onsite is about data sharing and documentation. This data sharing help to facilitate the review of records by other workers and promotes greater efficiency when engineering personnel are transferred or reassigned between different projects or even different project offices.

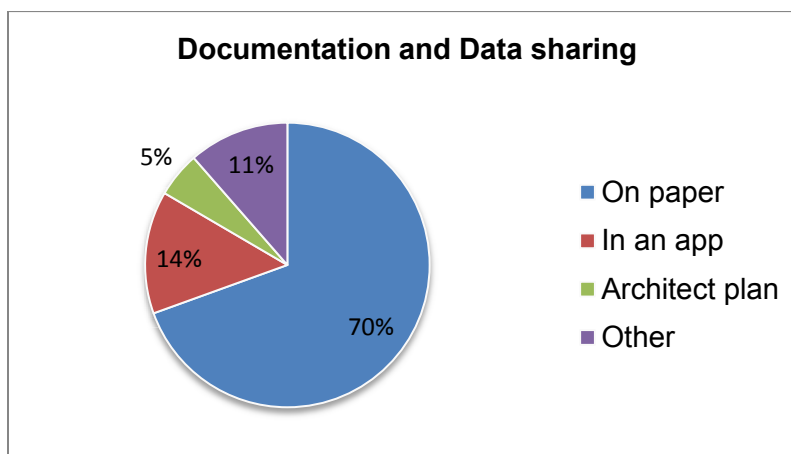


Fig 26: Documentation and data sharing usage by respondents

Documentation and data sharing help the construction worker to identify problems prior to the beginning of work and make plans to rectify them. The original field notes and records can be easily prepared and maintained as the work progresses. As shown in figure 26 above, 70% out of 161 respondents still document their measures in a conventional way on paper or the architect plan whereas only 14% out of 161 respondents use apps for documentation. According to the respondents, measuring data are mainly shared within the firm or with the architect for report change and

justification of final cost to a supplier for ordering that is why most of them prefer to document on a piece of paper. Also, according to the norms of the construction industry where a person is assigned to take in charge of measurements as the respondent commented.

“On every construction site, there is one person responsible for the plan and measures, which holds together all information” (Personal conversation, n.d)

There is high error rate of manual measure transfers of measurement, this offers great potential for app-based documentation Solutions. The key challenges of measuring with an LDM are related to the gear itself and the circumstances on the construction site.

5.3 Insight of app usage by respondents

Among the 169 interviewees, 161 respondents completed the questionnaire. Majority of the respondents use apps for their work and value simplicity and connectivity. As presented in figure 27 below a total of 70% out of 161 respondents construction trades use apps in their daily work. Out of that, Mechanical installation make up of 89% out of 161 respondents of majority trade which uses said app during their daily work. This is followed by Electrical installation which make up of 64% out of 161 respondents Majority of the respondents named non-construction related and supplier apps as what they use for sharing documentation and data especially with the mechanical installation.

The results show that using construction app onsite is prominent but response from the respondent shows that generation gap in willingness to use the apps is a major setback in most of the construction industry. Construction workers do not have the technical know-how on how to use the apps on the construction site.

Another feedback from most of the respondents is that they do not use an App in combination with their LDM; this is because they are not aware of its existence. Some of them responded that they are always having issues with missing connectivity, while others commented that it is complicated & not practical to combine the app and LDM.

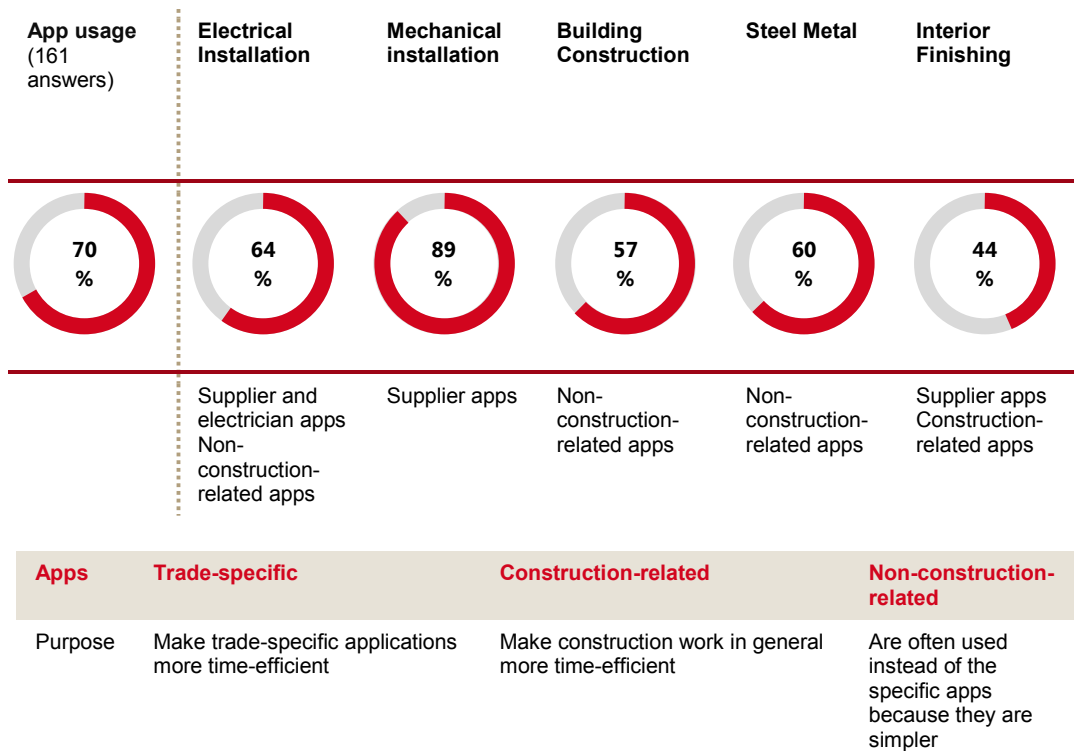


Fig 27: Insight of app usage by respondents

The responses from respondents, suggests that mobile app integration with LDM has a future in the construction market. Construction industries need to know the type of app and LDM to use for its workers since there is an abundance of apps available in the market, so it is difficult to know which one is easy to use and good for their job. Calculator apps are the most important used by many of the respondent's especially mechanical installation, followed by info- and product-apps.

5.4 Method and survey question

As shown in table 5, the survey was structured to understand and have deep knowledge in the LDM and construction app and the desired feature that can help LDM penetrate the construction trade market.

Table 5: Interview and question conducted outline

Interview	Questionnaire
<p>→ to deeply understand the LDM user's pain points and desired app features</p> <p>27 Interview Partners</p> <ul style="list-style-type: none">▪ Minimum 5 interviews per trade▪ Mainly foremen and small company owners▪ Companies with 5 to 100 employees represented	<p>→ to have a broader view on app and LDM use, and validate interview results</p> <p>Questionnaire</p> <ul style="list-style-type: none">▪ Mobile apps use (1-2 questions)▪ LDM use (2-3 questions)▪ Wish-list for measuring-related app <p>169 Respondents</p> <ul style="list-style-type: none">▪ Members of key trade-related Facebook groups in DACH region (134 respondents)▪ Finnish control group consisting of project managers, architects and civil engineers (35 respondents)

In the survey, a minimum of 5 interviews per trade was conducted; these interviews were performed mainly with professional construction workers. These professionals were foremen and small company owners. Most of the companies interviewed have employees between 5 to 100.

The questionnaire was slightly different compared to the interview, because the questions formulated in the survey was between 2-3 and key trade-related community group were targeted. Majority of the respondents were from Germany, Austria,

Switzerland (DACH), and the 35 respondents were from the Finnish control group consisting of project managers, architect and civil engineers.

The summary overviews in table 6 describe the partners who participated in the survey.

Table 6: Summary overview of interview partners

Summary				
<ul style="list-style-type: none"> Interviewees were selected and contacting active community members (e.g. on Facebook) Participants were mainly foremen and small company owners Companies with 5 to 500 employees represented, however majority with <100 employees 				
Professional titles of interviewees by trade				
Electrical installation 1. Electrician 2. Electrician 3. Electrician 4. Electrician 5. Electrician	Mechanical installation 1. Mechanic installer 2. Mechanic installer 3. Mechanic installer 4. Mechanic installer 5. Mechanic installer	Concrete works, masonry, restoration 1. Site foreman 2. Mason 3. Site foreman 4. Foreman 5. Site foreman	Roofing, decking, cladding 1. Roofer 2. Carpenter 3. Roofer & tin smith 4. Roofer 5. Roofer	Drywall contractors, suspended ceiling 1. Carpenter, draftsman 2. Plasterer 3. Plasterer 4. Plasterer 5. Plasterer, CEO 6. Plasterer and CEO 7. Plasterer

The interview was not recorded as mentioned in the research method, since there was limited time for this study. This method is time-consuming but did not affect the result of the data outcome. The questionnaire is shown below in table 7 and 8.

The interview questionnaire had four sections and 11 questions which helped to answer the research questions and to get an unbiased result.

Table 7: Questionnaire used in the survey

1. Mobile application use	2. General measuring	3. LDM measuring	4. Measuring apps
<ol style="list-style-type: none"> 1. Do you already use any mobile applications in your daily workflows? 2. If yes: Which mobile apps? 3. For which applications / workflows? 	<ol style="list-style-type: none"> 4. Which tasks in your job / daily work involve measuring distances? 	<ol style="list-style-type: none"> 5. Do you use Laser Dist Meters? If yes, which product? 6. For what kind of tasks do you (not) use your Laser Dist Meter? 7. How do you document your measurements? 8. Do you share your measures/ data with other trades? Why? / Why not? 9. What kind of challenges do you encounter when measuring with a LDM? 	<ol style="list-style-type: none"> 10. Do you use a mobile application in connection with your Laser Dist Meter? 11. What do you think are the most important features of such a mobile application?

The online survey questionnaire had four sections and was translated to German and Finnish. Even though it is very difficult to know which people answered the questions in the community platform, it is believed that professional construction workers are the only people registered under this active community.

As mentioned early in the scope and limitation section the internal survey question will not be shown for confidential reason.

Table 8: Online questionnaire used in the survey

1. Background info	2. General measuring	3. LDM measuring	4. Measuring apps
1. Which trade are you working at?	2. Are you using any mobile apps in your daily work? (Yes, No) 3. If yes, can you please list the most important ones? (open-ended)	4. Does your work include measuring with a Laser Dist Meter? (Yes, No) If answer is "No", survey ends here 5. What are your main pain points during measuring and measuring related processes? (open-ended) 6. How do you document measurement data? (Paper, software, mobile app, other + open-ended)	7. If there was a measuring related mobile app what kind of features should it have? (open-ended)

As it can be seen in figure 28 by the online survey results, Mechanical and Electrical installation workers dominated by 42% and 34% respectively. This is because these trades are highly active in Facebook communities where the survey was posted. Building Construction trade was the least with only 4% respondent not using LDM and measuring app.

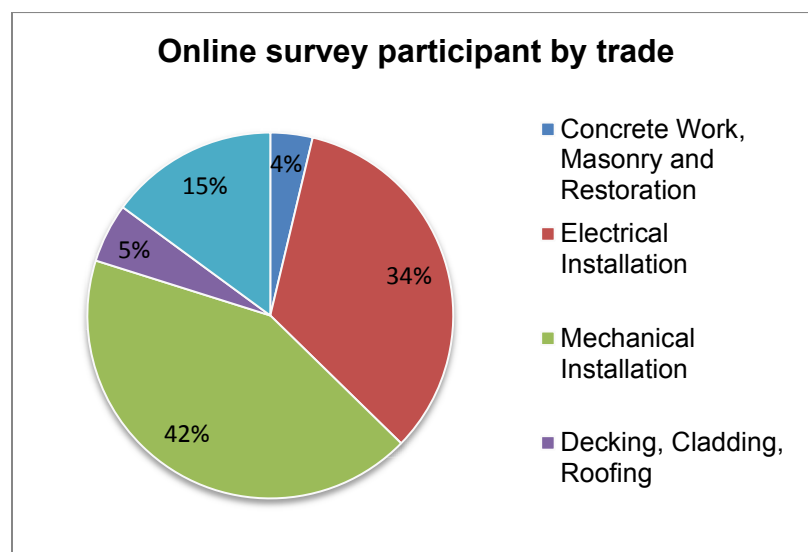


Fig 28: Online survey result

The Finnish participants represented mostly project managers, architects and civil engineers; the data was mainly used for cross-checking and documented separately.

5.5 Result from selected construction trades

This section describes the outline of the interview and survey and how the questions were structured to be able to answer the RQ2 'major pain-points and challenges construction workers face' and RQ3 'existing mobile application in the construction market'. Each construction trade was analyzed to answer the research questions.












5.5.1 Building construction

Building construction workers engage in both documentation and layout measuring. They actively employ various laser gears such as rotation-laser and tachymeters. 64% of the respondents use laser distance meter in their work while 36% of them do not use laser distance meter.

Despite calculation and estimation being the most important app category used by construction workers as shown in the table 10 below, wide variety of trade specific calculators operate only on either Android or iOS, thus making collaboration less attractive.

Overall, trade offers little amount of measuring related applications relevant for the case company. Most of the respondents which make up 45% document their measurements on paper, while 33% of them document measurement on the wall. It is therefore very necessary to substitute paper with digital documentation to have efficiency at the work place.

Table 10: App category BC

App Category	Features	Examples (incl. # of downloads)	Importance (category/total apps screened) *
Calculation & Estimation	Calculators, formulas, clinometers, picture-based measurement estimation	<ul style="list-style-type: none"> Construction Calculator (100'000)  Brick Arch Calculator (10'000)  	25/34
Trade-specific Information	Trade-standards, norms, process guidelines, safety standards, application videos, best practices news, discussion forms	<ul style="list-style-type: none"> Concrete Technology (50'000)  Concrete Hub (1'000)  	6/34
Product Info and ordering	Product catalogue, prices, ordering functions, supplier contact details, order logs, delivery tracking	<ul style="list-style-type: none"> Doka-tools (5'000)  Ozinga Concrete Calculator (1'000)  	5/34
Design and Visualization	Trade-specific design, visualization of expected outcome	<ul style="list-style-type: none"> Concretech, Reinforced Concrete design Pro (10'000)  Doka Augmented Reality (1'000)  	4/34
Education	Exam preparation material, exercises, tutorials, application videos	<ul style="list-style-type: none"> Structural Design Engineering (100'000)  Concrete Technology (50'000)  	3/34
Others	Project management, etc.	<ul style="list-style-type: none"> Smart Concrete™ (500)  	2/34

From the survey and interview 57% of the respondents use app in their daily work, while 43% of them do not. Despite the wide range of existing, trade-specific applications, interviewees mostly consume simple, non-construction-related apps. For example, WhatsApp is a popular for sharing evidence and weather apps are frequently mentioned. Some of the apps mentioned by the respondents can be found in the table 11 below.

Table 11: *Types of apps mentioned*

Trade-specific	Construction-related	Non-construction-related
<ul style="list-style-type: none">▪ Schmid Jammer (I)▪ Doka Tools (S)▪ ELO (I)	<ul style="list-style-type: none">▪ Sorba (Project management, Bookkeeping)▪ Bosch Toolbox▪ Hilti on Track	<ul style="list-style-type: none">▪ Weather app▪ Google Maps / Route planner▪ (Phone) directory▪ Calculator▪ Outlook▪ Calendar▪ Camera & video

Pain-point from respondents (LDM measuring)

“I see that there is a potential to share data. However, unions cannot agree on one standard and thus this is likely to come up only very slowly.” (Source: From respondent)

- Cannot see the point in long distances, due to sunlight or rain
- Pointing towards the wrong point
- Confusing the numbers when writing them down

There is potential to substitute physical data documentation with the digital. This would solve the pain point of “confusing the numbers when writing them down” and increase data sharing among different stakeholders.

List of Features for Building Construction

Table 12: List of features by respondents

1 = low, 2 = medium, 3 = high

Feature	Description	User Demand	Ease of Implementation	Availability
Calculation	Amounts of cement, bricks, volumes in general	3	2	✓
Measure converter		2	3	✓
Do a sketch & add measures	Documentation	2	2	✓
Data categorization	Labeling possibility for things that can/cannot be changed ("locking")	3	3	✓
Voice documentation	Voice notes to prevent misunderstandings and	3	3	✓
Add evidence pictures & video	Function to share data internally and with suppliers for material-orders	3	3	✓
Register construction site	Add details specific to construction site such as contacts	1	3	✓
GPS location tagging	Tag note/pic to specific GPS point	2	3	✓
Data sharing/exporting	Instant mail, PDF, chat, picture sending possibility from an app	3	3	✓
Material cost estimation	Cost estimation based on volumes and other measures (need for price localization)	1	2	✓








For concrete, masonry and restoration workers, must-haves of a measuring-related are calculation & measure converter, adding picture/video/voice evidence and exporting & labelling data. All this is covered by the key measuring-related apps available as soon in table 12 above.

5.5.2 Interior Finishing

For the construction of drywalls and suspended ceilings, measuring plays a crucial role before and after the completion of the construction process. Due to high convenience, LDMs are broadly used in this trade by 96% of the respondents. Additionally, line and rotation lasers are applied for positioning purposes.

84% of the respondents in drywalls and suspended ceiling mainly document their measurements by hand on paper or the plan provided by the architect. At the same time, as presented in table 13 below calculation and estimation is the most important app category used by the interior finishing trade.

Table 13: App category IF

App Category	Features	Examples (incl. # of downloads)	Importance (category/total apps screened) *
Calculation & Estimation	Calculators to derive surfaces and estimates for material usage and costs	<ul style="list-style-type: none"> – Suspended Ceiling Calc Lite (10'000)  – Drywall Calculator (5'000)  	16/24
Trade-specific Information	Standards and norms, process guidelines, news, knowledge sharing	<ul style="list-style-type: none"> – Knauf Infothek (1'000)  – Drywall Talk  	6/24
Product Info and ordering	Product catalogues, direct ordering and company contacts	<ul style="list-style-type: none"> – Rigips Austria (5'000)  – fermacell app (5'000)  	7/24
Education	Installation tutorials	<ul style="list-style-type: none"> – GIPS (100)  	1/24

Additionally, 44% of the respondents uses app in their daily work against majority who do not that is 56%. This shows that only about half of the respondents already use apps in their daily work. They mainly use apps provided by suppliers or general construction-related apps. Usually, only the final measures are shared with the architect. Some of the apps mentioned by the respondents are represented in table 14 below.

Table 14: *Types of app mentioned*

Trade-specific	Construction-related	Non-construction-related
<ul style="list-style-type: none"> ▪ Knauf ▪ Rigips 	<ul style="list-style-type: none"> ▪ NCS color identifier ▪ PlanRadar ▪ Seek thermal ▪ Sorba ▪ TimeSheet ▪ Werkzeugkiste 	<ul style="list-style-type: none"> ▪ WhatsApp

Pain-point from respondents (LDM measuring)

- Strong sunlight decreases visibility of laser point
- Walls with no end require to measure in twos or creativity
- Line laser and LDM are not integrated
- Transfer of measurements and remembering measuring process
- Battery change

List of Features for Interior Finishing

Table 15: List of features from respondents

1 = low, 2 = medium, 3 = high

Feature	Description	User Demand	Ease of Implementation	Availability
Calculation	Add and subtract measurements (i.e. distances), automatic calculation areas and volumes	3	3	✓
Export function	Compatibility with and automatic transfer of measures to CAD and planning software	3	3	✓
Picture	Take a picture, integrate measurements, see how outcome will look like	3	2	✓
Process guide	Guided process to take final measures ("Ausmass") based on RfP where positions can be confirmed or adapted	2	2	✓
Surface recognition	Automatic recognition of walls, surfaces and relevant distances based on picture of plan or situation	2	1	×

For Interior Finishing, must-haves of a measuring-related are calculation, data export and picture features which are covered by the key measuring-related apps available as shown in table 15 above.






5.5.3 Steel-Metal

Surface area measuring is the central part of roofing, decking and cladding workflow. Drones disrupt the trade as they offer potential to simplify roof measuring process (no need to go on the roof), this saves time and increases safety. About 60% of the respondents in the survey and interview use LDM in their daily work whiles 40% of them do not use. This shows that majority of steel metal contractors do use LDM.

Measurement data is mainly shared with architects, thus 33% of workers document measurements mostly by hand straight on the architect plan or sketch. The Use of LDM

in the measuring process is limited due to many challenges. Interviewees mostly consume simple, non-construction related apps, as according to them existing construction apps don't cover all their needs. Calculation & material estimation and design & visualization categories are the most important for the trade as seen in table 16 below, and the most relevant for case company in terms of LDM collaboration.

Table 16: App category SM

App Category	Features	Examples (incl. # of downloads)	Importance (category/total apps screened) *
Calculation & Estimation	Calculators, formulas, clinometers, picture-based measurement estimation	– Pitch Gauge (100'000) 	20/26
Trade-specific Information	Trade-standards, norms, process guidelines, safety standards, application videos, best practices, news, discussion forms	– AS/AR Gebäudehülle Schweiz (100) 	2/26
Product Info and ordering	Product catalogue, prices, ordering functions, supplier contact details, order logs, delivery tracking	– iRoofing (1'000) 	4/26
Design and Visualization	Trade-specific design, visualization of expected outcome	– iRoofing (1'000) 	15/26
Others	Project management, data annotation	– Dataforma 2.0 (5'000, project management) 	4/26

Only one interviewee mentioned that data is shared with other trades. About 60% of them use the app in their daily work to make their job easier. Some of the apps they mention in the survey and interview which they work with are shown in table 17 below.

Table 17: Apps mentioned by respondents

Trade-specific	Construction-related	Non-construction-related
<ul style="list-style-type: none"> ▪ AS/AR Gebäudehülle Schweiz (industry norms) ▪ Clinometer ▪ ImageMeter - photo measure ▪ Rathscheck "Schiefer-Tools" 	<ul style="list-style-type: none"> ▪ Measuring master (Bosch) ▪ Makita Smartool 	<ul style="list-style-type: none"> ▪ Calculator ▪ Outlook ▪ Calendar ▪ Camera & video ▪ Dropbox ▪ OneNote ▪ Nextcloud ▪ Flashlight

Pain-point from respondents (LDM measuring)

“The pre-measures are only kept within the firm. The final measures (“Ausmass”) are shared with the architect to justify the bill.” (Source: From respondent)

- Not seeing the point due to sunlight or rain
- No endpoint on the roofs, therefore need to measure in pairs
- Battery running out in the cold
- Some materials like aluminum reflect laser rendering inaccurate.

List of Features for Interior Finishing

Table 18: List of features from respondents

1 = low, 2 = medium, 3 = high

Feature	Description	User Demand	Ease of Implementation	Availability
Split of tiles	E.g. if I am measuring the "Spärenlänge" and I know the "Dachaufbau" the app should give me directly the split of tiles to put on the roof, e.g. where I need to fix the "Latten".	2	1	×
Calculation of materials	How much of which material to order to deck a roof based on the measured square meters net of chimneys and roof	2	3	✓
Do a sketch & add measures	Documentation and transfer to cloud	3	2	✓
Simplicity and time efficiency	Basics in one place and easy to learn to use	3	3	✓
Picture based measuring/Drone picture to CAD	Calculating lengths, angels and heights.	2	1	×
Working hours tracking		1	2	✓
Possibility to connect LDMs to an app	Via Bluetooth or Wi-Fi	3	2	✓
Adding buildings to central database	To share with other trades and avoid measuring same building many times	3	1	✓







For Steel Metal work, must-haves of measuring-related apps are calculation, data export, and doing a sketch which is covered by the key measuring-related apps available. As shown in table 18 above.

5.5.4 Mechanical Installation

Measuring is a crucial part of mechanical installations (position of installation and length of auxiliaries). However, most distances are not very long, and traditional measuring tools can be used as well, resulting in a 35% lower rate of respondents using their LDMs daily. They use LDM to determine the ideal placement of an installation (i.e. heating system, sanitary facilities) and to measure dimensions for pipes and other material connected to the installations Mechanical installation faces the same non-trade specific issues as other trades. About 79% of the respondent's document on paper while 21% already share documents measurements digitally. A significant number of them use apps daily in their work which represents 89% respondents.

These apps are provided by manufacturers or suppliers of mechanical systems – these apps often include a calculation tool and allow placing an order based on the measurement results as it is shown in the table 19 below.

Table 19: App Category Mechanical

App Category	Features	Examples (incl. # of downloads)	Importance (category/total apps screened) *
Calculation & Estimation	Calculators for heating systems, pressure etc.	<ul style="list-style-type: none"> HyTools (50'000+)  Reflex Pro App (10'000+)  	20/26
Trade-specific Information	Collection of manuals, installation advice etc.	<ul style="list-style-type: none"> Danfoss HS (100'000+)  	2/26
Product Info and ordering	Product catalogues, information, online shops	<ul style="list-style-type: none"> Viessmann Ersatzteil-App (100'000+)  Geberit ProApp (50'000+)  	4/26
Design and Visualization	Tools that use VR / AR to showcase products before installing them	<ul style="list-style-type: none"> Villeroy & Boch Augmented Reality (5'000+)  	15/26

Access to installation instructions and manuals is a key factor. While there are many apps targeted at mechanical installations, diversity is low – most applications are provided by manufacturers or suppliers and help with selling, installing, maintaining or ordering processes.

Table 20: Apps mention by respondents

Trade-specific	Construction-related	Non-construction-related
<ul style="list-style-type: none"> ▪ Apps by key manufacturers: Buderus /Vaillant / Junkers / Viessmann / Wolf / Danfoss / Bosch ▪ Wholesale ordering apps: e.g. GC Group ▪ Calculation programs for e.g. 'Heizlast' ▪ Tado 	<ul style="list-style-type: none"> ▪ ViSoft Smart ▪ CamtoPlan 	<ul style="list-style-type: none"> ▪ GoodNotes ▪ MasterTask ▪ Trello ▪ Maps ▪ WhatsApp

Some apps mentioned by the respondents are shown in table 20 above.

Pain-point from respondents (LDM measuring)

“All measurement results need to be integrated into our in-house software” (source: From respondent)

- Laser point visibility in light circumstances
- For some distances the laser is not strong enough
- Can be hard to aim and to not shake
- Battery runs out
- No possibility to directly use the data to conduct calculations (e.g. on material needed)

List of Features for Mechanical Installation

Table 21: List of features from respondents

1 = low, 2 = medium, 3 = high









Feature	Description	User Demand	Ease of Implementation	Availability
Connectivity	Very easy pairing to LDMs from any brand, extremely flexible export of measurement data	3	1	✓
Simplicity	Existing apps were criticized for being too complicated (e.g. 'I don't want to draw walls')	3	1	✓
Mapping of rooms	Some respondents described features very similar to existing solutions	2	2	✓
Integration with existing planning tools	BIM / CAD tools are becoming more important, measurement data should integrate flawlessly	3	2	x
All LDM brands	Compatibility to all Bluetooth-enabled LDMs	3	1	✓
Automated measuring process	Mapping an entire room by walking through it (and taking various measurements)	1	3	x

For mechanical installation, the most sought-after features center on simple and flexible solutions as well as the possibility to export the data in many ways and integrate it to various planning / management tools. The wish list by the respondents is shown in table 21 above.

5.5.5 Electrical Installations

Measuring in electrical installation is used to determine installation-location, create tenders/bills. LDMs are mainly used to measure distances of more than two meters. Electricians face several non-trade-specific challenges when measuring with an LDM that is why minority which is about 52% of the respondents uses LDM in their daily work. About 77% of measurements are mainly documented on paper and only shared with third parties for material orders. Another 66% of Electricians use a lot of supplier apps to order material as well as simple, non-construction-related apps to calculate, document (notes, audio, Dropbox), and communicate (WhatsApp, outlook) as shown in table 22 below.

Table 22: App category Electricals

App Category	Features	Examples (incl. # of downloads)	Importance (category/total apps screened) *
Calculation & Estimation	Calculators for power, voltage drop, etc	<ul style="list-style-type: none"> – Electrical Pro (5'000)  – Electrical Calc Elite (1'000)  	27/59
Trade-specific Information	Norms, IP-codes, color codes, illuminance, etc.	<ul style="list-style-type: none"> – Elektro-Memory (50'000)  	19/59
Product Info and ordering	Product catalogues, order tracking, etc.	<ul style="list-style-type: none"> – Otto Fischer (5'000)  – Winterhalter + Fenner AG (10'000)  	10/59
Design and Visualization	Product visualization (by supplier), etc.	<ul style="list-style-type: none"> – ZPlan.mobile Zählerplatz Hager (10'000)  	6/59
Education	Exam preparation guide, exercises, games (i.e. quiz	<ul style="list-style-type: none"> – Elektro-Memory (50'000)  	13/59
Others	Sat-finder, heatmapping	<ul style="list-style-type: none"> – SatFinder (5'000'000)  	3/59

There is a variety of electrician apps, mostly calculators as presented in table 23 above. However, not all of them need distance measurements as input data since a lot of them are about power. Norms and standards are very important in this trade (in terms of safety), thus a lot of information, as well as education apps, are supplied as well.

Table 23: Apps mentioned by respondents

Trade-specific	Construction-related	Non-construction-related
<ul style="list-style-type: none"> ▪ Electro Tools (7) ▪ Sonepar AT (3, S) ▪ Sonepar E-Helfer (2, S) ▪ Otto Fischer (2, S) ▪ Winterhalter + Fenner (S) ▪ Obeta Shopping (S) ▪ Junkers Scan (Bosch) (S) ▪ Busch-Jäger Lichtschalter (S) ▪ Gira Design Configurator (S) ▪ ZPlan.mobile ▪ Zählerplatz Hager (S) ▪ CKW-apps (I) ▪ nisXplorer (e.g.Heatmapping) ▪ SatFinder 	<ul style="list-style-type: none"> ▪ Hilti on Track (2) ▪ Fluke Connect (2) ▪ Bosch easy service ▪ Fieldwire ▪ KWP info 	<ul style="list-style-type: none"> ▪ WhatsApp (7) ▪ Outlook / Calendar ▪ TeamViewer ▪ Time tracking ▪ Calculator ▪ Camera ▪ Flashlight ▪ Maps ▪ Notes / OneNote / Evernote ▪ Recorder ▪ Dropbox ▪ Google / Safari

Pain-point from respondents (LDM measuring)

“When ordering material, I share measurement information with our supplier.” (Source: From respondent)

- Laser cannot be seen in light (e.g. sun)
- Some materials reflect the laser
- Laser is not strong enough for some distances
- Can be hard to aim and to not shake
- Battery runs out
- Restricted availability of LDMs
- Process is time-consuming
- Different measurement-results for the same measurement.

List of Features for Electrical installation

Table 24: List of features from respondents

1 = low, 2 = medium, 3 = high

Feature	Description	User Demand	Ease of Implementation	Availability
Picture	Take a picture, integrate measurements, see how outcome will look like	3	3	✓
Label/Locate/Notes	Label measurements (e.g. trace XY), add location of customer, add notes (written, audio)	3	2	✓
2D or 3D model	Display the measurements in a 2D or even better 3D model	2	2	✓
Calculation	Add and subtract measurements (i.e. distances), calculate areas and volumes	3	3	✓
Export function	Export the measurements to other programs/ systems (i.e. to a system where the illumination of a room is calculated)	3	1	×
Sharing	Function to share data internally and with suppliers for material-orders	1	2	×

For electricians, a measuring-related app should include basic functions such as the possibility to add pictures and notes to the measurements, calculate with the measurements, display the results in a model, as well as export and share the data. Table 24 above shows the wish list of the respondents.

5.6 App screening

This sub-chapter answer the RQ 4: What are the most relevant apps for each construction trade and their business potential?

A total number of 150 construction related app and 170 trade specific apps were screened and documented from various sources and some of these sources are google play store, iTunes store results for 'shk' app search query, App overview brochure by shk trade magazine 'Si', Recommended apps in a blog post on 'energieheld.de' Collection of useful apps on a Facebook community.

Out of the apps screened, 90 were measuring related calculator apps which are mostly used by construction workers, followed by info- and product-apps. These apps were clustered into 30 categories, based on Simplicity, connectivity, documentation and data features as shown below in figure 29 to answer the RQ 4.

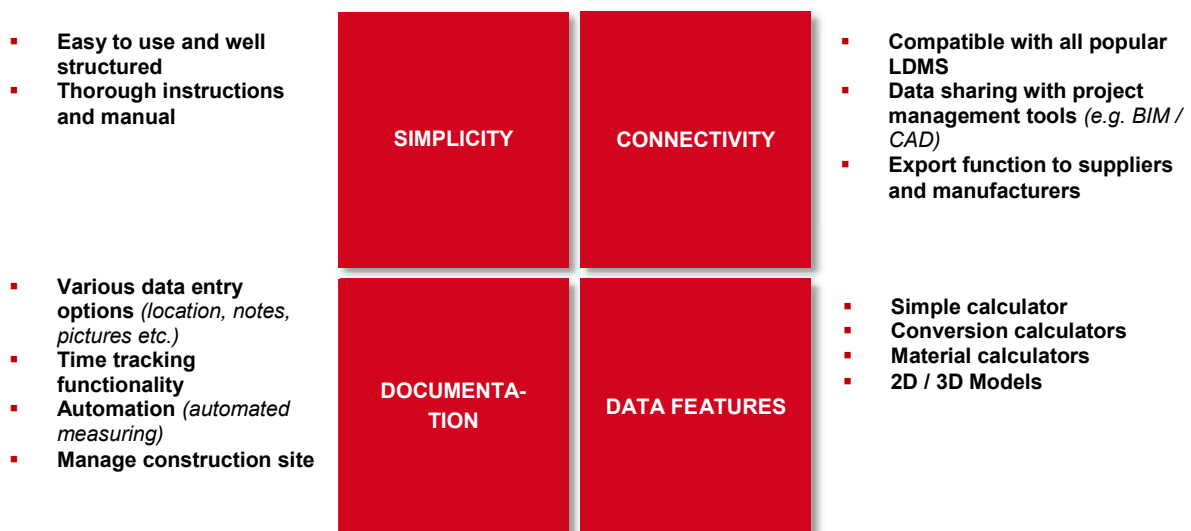


Fig 29: Features selected for app screening

The app needs to be basic, clearly structured and time efficient to serve its purpose for the end user. Its thorough instructions and manual how to achieve best measurement results, since most of the construction workers have the technical knowledge in using LDM integrated with an app. The app needs to be compatible with all popular LDM

brands and easily integrate measures. Data sharing with project management tools (e.g. BIM / CAD) should be easily done.

Export function to suppliers and manufacturers in various formats with any channel. The measurements can be tagged with all kinds of corresponding data – GPS location, notes pictures, (drone) videos, voice commands. Capturing the time spent at the construction site taking measurements is a vital issue which was taking into consideration. Create shareable output and add to a database was a major pain-point that most construction workers want.

Since most of the job done on construction site is about measurement, there should be an app which can easily make site calculation and transform measurements. Use measurements to determine the amount of material needed (e.g. # of tiles, wall paint). The clustered selected apps are presented in figure 30 below.

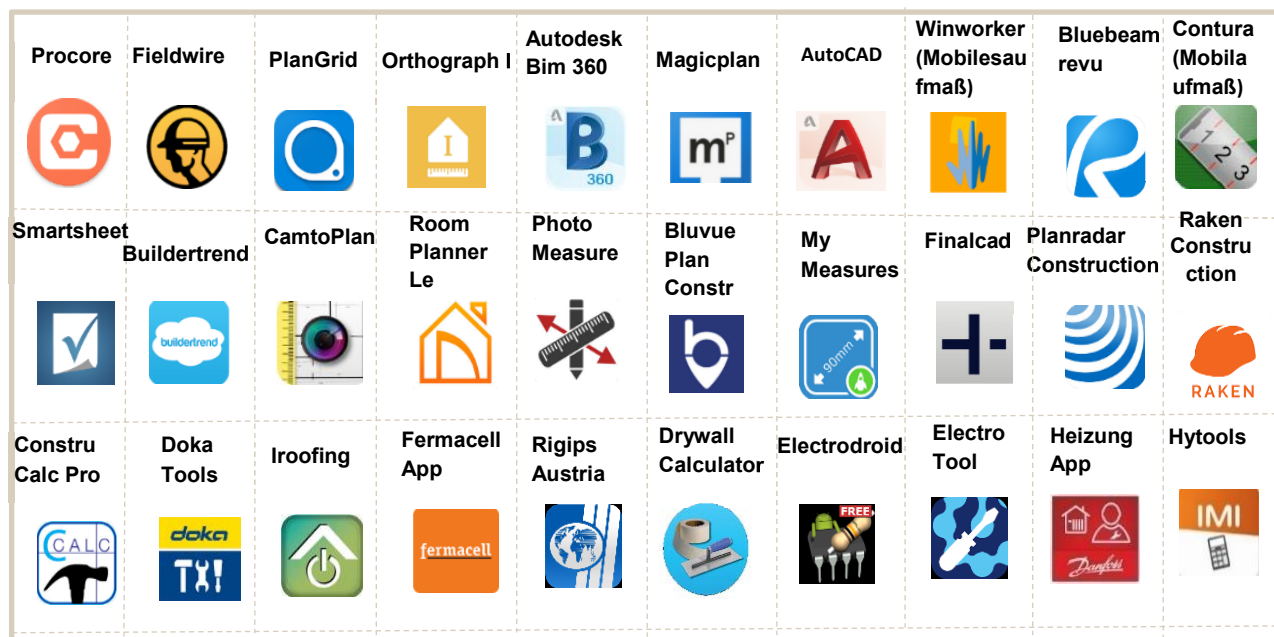


Fig 30: Clustered construction mobile apps selected

6 Conclusion and Recommendation

This final chapter describes about the limitations in the thesis and the evaluations of the construction mobile apps and further research to be done.

6.1 Contribution and Limitations

There is no uncertainty digitalisation is the future of the construction industry. As digitalisation evolves and advances, the construction industry continues to develop. Currently, the biggest problem in a construction project management and data documentation is paperwork and real-time information sharing; the research shows that integrating mobile app strategy and laser distance meter can help construction industry increase productivity and efficiency onsite.

Several construction mobile apps were discovered during this research study, most of the apps are used in the construction site during the early phase of construction work.

The most frequent mentioned apps by the construction professionals are calculation and cost estimation apps. Most of the workers need in each phase of their job but we can conclude that they also face some challenges in using the apps together with the laser distance meter even though, using LDM is faster than the traditional way of working.

Majority of the professional construction workers specified the usefulness of having an app which can easily estimate the number of bricks, tiles or paint that can be used in a building, especially with interior finishing contractors. It was discovered in the research that most of the construction workers lack technical knowledge in using the app and laser distance meter in the construction site. This means conducting proper training in the construction industry is essential.

Another problem which was identified in the research was difficulty in viewing measurement on the laser distance meter and viewing document on the mobile device. The construction industry has been moving in slow pace to apprehend the opportunities arising in the mobile application world.

The advantages of using laser distance meter with an app is enormous, accessing measurement, collecting data and updating construction projects is a means of ensuring that the data is accurate. This does not only improve efficiency but also help in decision making onsite.

It is therefore very important to integrate laser distance meter with mobile application to respond to customer needs, expand service offering and finally penetrate the construction trades. With the integration of laser distance meter with various construction mobile apps, there will be competition from different laser distance manufacturer, it is therefore very important to analyses the various mobile apps available so that consumers demand can be attained.

Some of the limitations in this research were the fact that, trade descriptions and definitions vary among different documents and countries which made analysis a bit difficult, so the best option was to combine certain trades so that it can be analysed. There will be a better option to have the same description for each construction trade in all countries.

6.2 Evaluation

The selected 30 construction apps were determine based on the value added for the case company and easy penetration In the construction trades. The app rating from app store and interview results were combined to determine the app with the higher priority for the case company.

After combining the result, further evaluation was done based on the correlation between the usability, functions and data sharing and this was prioritize based on measuring relevance, number of download of the app which was carefully analysed since some apps are highly rated by google play store and Apple store and have market presence, whiles some are highly rated by users but have not yet achieve market presence.

The degree of connection between the usability, functions and data sharing is different for different app categories. There was a strong overall connection between the ratings given to the apps by their users and their popularity as indicated in the research analysis (that is how it is ranked by downloading. App categories were analysed for both free and non-free apps. It was found that free apps received significantly higher ratings than their non-free apps.



ROOM PLAN APP



**ISSUES & TASK
MANAGEMENT**



ANNOTATION APPS

Fig 31: Measuring functions for construction mobile app

More so, since the apps are analysed to find the best collaborator, some app where seen to have an important market presence and resources but receive below average user satisfaction. Others have the market presence in a specific country and are rated positively on customer satisfaction. It was considered whether the app is on iOS and Android and the app is not an internal app by screening them from various sources like google play store as mentioned in chapter 5. All these were considered to help in the evaluating the apps. The apps are clustered and evaluated according to their construction measuring function as shown in figure 31. The mobile apps are categorized under Room Plan App, Issues and Task Management and finally Annotation Apps to cluster them into their measuring functions.

6.3 Further research

There was also limited data available for the relevance measurements of laser distance meter for each construction trades. More research needs to be done in that aspect to understand the use of laser distance meter (LDM) in each phase of construction trade. Same app across multiple construction trade measurement need to be further analysed to know which specific trade the app support because this is a problem for the construction worker to know exactly in which trade to use the app when integrating with laser distance meter. Another related challenge worth for further research is checking the correctness and consistency of laser distance meter across different construction trade this will minimize the difficulty and effort in consistency checking the correctness and accuracy of the measurement taken by the construction worker and this can improve labor productivity.

7 References

- Abaffy, L., 2011. iPads and Tablets: Time Saved Vs. Time Spent. ENR: Engineering News-Record, 267(9), 20–20.
- Adriaanse, A.M., Voordijk, H. & Dewulf G.P.M.R., 2004. Alignment between ICT and communication in construction projects, Int. J. Human Resources Development and Management, Vol. 4, No. 4, pp.346–357.
- AIA, 2007. Integrated Project Delivery: A Guide. In: American Institute of Architects.
- Akyurt, E., 2018. Free Image on Pixabay - Construction, Daniel, Steel, Design. [Online] Pixabay.com. Available at: <https://pixabay.com/en/construction-daniel-steel-design-3433306/> [Accessed 8 Sep. 2018].
- ASSOCIATION OF ARCHITECTURAL ALUMINIUM MANUFACTURERS OF SOUTH AFRICA (AAANSA), 2007. [online] general specification for suspended ceilings. Available at: https://www.aaamsa.co.za/docs_new/SABISA/General_Specs_for_Ceilings.pdf. [Accessed 15 March. 2018].
- Atlas-Machinery Ltd, n.d. Bosch GLM50C Laser Distance Measurer with 165-Foot Range & Backlit Display & Bluetooth. [Online] Available at: <https://www.atlas-machinery.com/Bosch/Lasers/GLM50C> [Accessed 8 Sep. 2018].
- Bannafarsai, S., n.d.. Surveyor builder Engineer with theodolite transit equipment at construction site outdoors during surveying work. [Online] Shutterstock.com. Available at: <https://www.shutterstock.com/image-photo/surveyor-builder-engineer-theodolite-transit-equipment-747626554> [Accessed 9 Sep. 2018].

- Baracco-Miller, E., 1987. Planning for Construction, Unpublished MS Thesis, Dept. of Civil Engineering, Carnegie Mellon University.
- Bartolini, L., Bordone A., Fantoni R., Ferri de Collibus, M., Fornetti, G., Moriconi, C. & Poggi, C., 2000. DEVELOPMENT OF A LASER RANGE FINDER FOR THE ANTARCTIC PLATEAU. [online] Citeseerx.ist.psu.edu. Available at: <http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.572.5770>
- Baumanns, T., Freber, P.-S., Schober ,K.-S. & Kirchner, F., 2016. Bauwirtschaft im Wandel. Trends und Potenziale bis 2020. Available at: https://www.rolandberger.com/de/Publications/pub_construction_industry_in_transition.html. -Digitization in the construction industry. Building Europe's road to "Construction 4.0". Available at: https://www.rolandberger.com/en/Publications/pub_digitization_of_the_construction_industry.html. [Accessed 12 March. 2018].
- Bowden, S., Dorr, A., Thorpe, A. & Anumba, C., 2004. Mapping site processes for the introduction of mobile IT. Proceedings of the 5th European Conference on Product and Process Modelling in the Building and Construction Industry, Istanbul, Turkey.
- Bowden, S., Dorr, A., Thorpe, A., Anumba, C.J. & Gooding, P., 2005. Making the case for mobile IT in construction. Comput. Civ. Eng.1-12.doi:10.1061/40794(179)46.
- Bryman, A. & Emma, B., 2015. Business research methods. English. 4th ed. Oxford: Oxford Univ. Press. isbn: 9780199668649.

- Building and Construction Authority (BCA), 2002. CONQUAS Enhancement Series
Good Industry Good Industry Practices – [online] Drywall Internal Partition.
Available at: <https://www.bca.gov.sg/Publications/EnhancementSeries/dw.html>.
[Accessed 10 Aug. 2018].
- Building and Construction Authority (BCA), 2010. [online] Builders' Guide on Measuring
Productivity. Available at:
https://www.bca.gov.sg/Productivity/others/builders_guide_productivity.pdf
[Accessed 10 Aug. 2018].
- Building and Construction Authority (BCA), 2010. [Online] Builders' Guide on Measuring
Productivity. Available at:
https://www.bca.gov.sg/Productivity/others/builders_guide_productivity.pdf
[Accessed 10 Aug. 2018].
- Building and Construction Authority (BCA), 2017. [online] Facade Access Design Guide.
Available at:
https://www.bca.gov.sg/PerformanceBased/others/DM_FADG_2017.pdf
[Accessed 10 Aug. 2018].
- Carnes, T., 2005. Indoor sound criteria according to the American Society of Heating,
Refrigerating and Air-Conditioning Engineers (ASHRAE)—An introduction. The
Journal of the Acoustical Society of America, 118(3), pp.1843-1843.
- Chen, Y. & Kamara, J., 2008. The Mechanisms of Information Communication on
Construction Sites." FORUM Ejournal 8, June 2008:Newcastle University, 1-32.

- Chien, H., Barthorpe, S. & Shih, J., 2003. The potential for ERP (enterprise resource planning) in integrating the supply chain in the UK construction industry. *International Journal of Internet and Enterprise Management*, 1(2).
- Chrzanowski, A., 1984. Feasibility Study on the Implementation of the Motorized Trigonometric Height Traversing for Precise Levelling. Final Report of Contract with the Geodetic Survey Division of Energy, Mines, and Resources Canada, 1984 09 30, 100 pp.
- Cline, R. C. & Davis, K. A., 2013. Using Mobile Technology in a Construction Management “Hands-On” Laboratory Paper presented at 2013 ASEE Annual Conference & Exposition, Atlanta, Georgia. <https://peer.asee.org/22714>.
- Dagmara, K., n.d. Suspended Ceilings. Drywall ceiling.. [online] Shutterstock.com. Available at: <https://www.shutterstock.com/image-photo/suspended-ceilings-drywall-ceiling-574316404> [Accessed 8 Sep. 2018].
- Destatis, 2018. Produzierendes Gewerbe. Tätige Personen und Umsatz der Betriebe im Baugewerbe 2017. Available at: <https://www.destatis.de/DE/Publikationen/Thematisch/Bauen/BaugewerbeStruktur/PersonenUmsatzBaugewerbe.html>. [Accessed 14 March. 2018].
- Fuji, Y. & Maru, K., 2010. Precision instrumentation and measurement. Switzerland: Trans Tech Publications.
- Gaylord, E. & Gaylord, C., 1957. Design of steel structures, including applications in aluminum [by] Edwin H. Gaylord, Jr. [and] Charles N. Gaylord. New York: McGraw-Hill.

- GmbH, R., n.d. GLM 20 Professional, Laser Measure | Bosch. [Online] Bosch-professional.com. Available at: <http://www.bosch-professional.com/ng/en/laser-measure-glm-20-131500-0601072eg0.html> [Accessed 11 Aug. 2018].
- Hasan, M., Karim, A. & Brown, R., 2013. Investigation of Energy Efficient approaches for the energy performance improvement of commercial buildings. Queensland University of Technology, Australia: Master of Engineering (Research).
- Indypendenz, n.d. Carpenter working carefully looking at the plans work in carpentry. He is successful entrepreneur at his workplace. Hammering a nail Supports on Building Site work with cutter. [Online] Shutterstock.com. Available at: <https://www.shutterstock.com/image-photo/carpenter-working-carefully-looking-plans-work-1121717027> [Accessed 8 Sep. 2018].
- Infrastructure, B., Meters, L., Meter, F., Meter, F., & 424D, F., 1995. Fluke 424D Laser Distance Meter. [Online] Fluke.com. Available at: <https://www.fluke.com/en/product/building-infrastructure/laser-distance-meters/fluke-424d> [Accessed 8 Sep. 2018].
- Internet of case company 2018. Comparison of traditional method and laser distance measurement. Available at: <https://hilti.fusion-universal.com> [Accessed 8 July. 2018].
- Irene, B., Thomas, N. & Jörg, O., 2018. Contribution of Digitisation to Productivity in the Construction Industry. Available at: <https://www.zew.de/en/forschung/contribution-of-digitisation-to-productivity-in-the-construction-industry/?cHash=cff712e6a0c1518bc05706d1be7a8039>
- Jackson, M., 1986. Computers in construction planning and control. London a.o: Allen & Unwin.

- Joyce, E., 2011. ENR's Top 10 Construction Apps. (Cover story). ENR: Engineering News Record, 267(16).
- Kalinovsky, D., n.d. Line electrician builder engineer worker at indoor construction site cabling. [Online] Shutterstock.com. Available at: <https://www.shutterstock.com/image-photo/line-electrician-builder-engineer-worker-indoor-239157799?src=Q-DXx2ObMUcwzSguVK39lw-1-41> [Accessed 7 Feb. 2019].
- Khaleghi, B., 2010. Washington State Department of Transportation Plan for Accelerated Bridge Construction. Transportation Research Record: Journal of the Transportation Research Board, 2200(1), pp.3-11.
- KOF., 2017. Die europäische Bauwirtschaft boomt. Available at: <https://www.kof.ethz.ch/news-und-veranstaltungen/medien/medienmitteilungen/2017/11/die-europaeische-bauwirtschaft-boomt.html>. [Accessed 23 Apr. 2018].
- Korman, T., Simonian, L. & Speidel, E., 2010. How building information modelling has changed the MEP coordination process. Challenges, Opportunities and Solutions in Structural Engineering and Construction, Taylor & Francis, London, 959-963
- Kreith, F. & Goswami, D., 2005. The CRC handbook of mechanical engineering. Boca Raton [Fla.]: CRC Press.
- Kunz, J. & Fischer, M., 2012. Virtual Design and Construction: Themes, Case Studies and Implementation Suggestions | Center for Integrated Facility Engineering. [online] Cife.stanford.edu. Available at: <https://purl.stanford.edu/gg301vb3551> [Accessed 15 May. 2018].

- Laryea, S., 2011. Quality of tender documents: case studies from the UK. *Construction Management and Economics*, 29(3), pp.275-286.
- Lazada.com.ph, n.d. [Online] Available at: <https://www.lazada.com.ph/products/bosch-glm-50-c-professional-50-m-laser-rangefinder-with-bluetooth-measuring-tool-i101327962-s101505238.html> [Accessed 8 Sep. 2018].
- Liszewski, A., 2011. [Online] Gizmodo.com. Available at: <https://gizmodo.com/an-app-connected-laser-tape-measure-will-never-mistake-1459713322> [Accessed 8 Sep. 2018].
- Löfgren, A., 2007. "Mobility in-Site: Implementing Mobile Computing in a Construction Enterprise." *Communications of the Association for Information Systems*, 20(1/37), 1-12. <http://aisel.aisnet.org/cais/vol20/iss1/37>
- María González, E., 2018. Easterby-Smith, M; Thorpe, R.; Loewe, A. (1991): *Management Research, an Introduction*. London, Sage. Questiones Publicitarias. 89. 10.5565/rev/qp. 209.
- McKinsey, 2017. Reinventing construction: [online] A route to higher productivity. Available at: <https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/reinventing-construction-through-a-productivity-revolution>. [Accessed 12 March. 2018].
- Michael, T., 2018. What Does MEP Mean in Construction? Available at: <https://www.ny-engineers.com/blog/what-does-mep-mean-in-construction>. [Accessed 05 Jun. 2018].
- Miller, M., Miller, R. & Baker, G., 2004. *Carpentry & construction*. New York: McGraw-Hill.

- Mine, N., Olanrewaju, A. & Takeuchi, M., 2014. Learning Effect of Interior Finishing and Building Services Works for Multi-Dwelling Complex Project. Proceedings of the 31st International Symposium on Automation and Robotics in Construction and Mining (ISARC).
- Mobile Man, 2015. How Mobile Technology is Transforming the Construction Industry. Available at:
<https://www.infragistics.com/community/blogs/b/mobileman/posts/how-mobile-technology-is-transforming-the-construction-industry>. [Accessed 7 Apr. 2018].
- Mohamed, S. & Stewart, R., 2003. "An Empirical Investigation of Users' Perceptions of Web-based Communication on a Construction Project." *Automation in Construction*, 12(1): 43-53.
- Morgan, S., 2009. Improving Productivity and Efficiency through Mobile Technology Solutions. [Online] For Construction Pros. Available at:
<https://www.forconstructionpros.com/construction-technology/article/10291573/construction-technology-for-improving-productivity-and-efficiency-through-mobile-solutions> [Accessed 17 Jun. 2018].
- Morse, J. M., 2003. Principles of mixed methods and multimethod research design. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social & behavioral research* (pp. 189-208). Thousand Oaks, CA: Sage.
- Mudarri, D. & Fisk, W., 2007. Public health and economic impact of dampness and mold. *Indoor Air*, 17(3), pp.226-235.

- Nakashima Degarrod, L., 2010. When ethnographies enter art gallery.” in Museum Materialities: Objects, Engagements, Interpretations, S. H. Dudley (London, New York: Routledge, 130.
- Rackham, J., Couchman, G., & Hicks, S., 2009. Composite slabs and beams using steel decking. Wirral, Cheshire: Metal Cladding & Roofing Manufacturers Association in partnership with the Steel Construction Institute.
- Radziszewska-Zielina, E., 2014. A comparative analysis of selected parameters of roofing used in the Polish construction industry. Selected Scientific Papers - Journal of Civil Engineering, 9(1), pp.41-50.
- Ratnikov, V., n.d.. Concrete pouring during commercial concreting floors of buildings in construction. [Online] Shutterstock.com. Available at:
<https://www.shutterstock.com/image-photo/concrete-pouring-during-commercial-concreting-floors-94237147> [Accessed 7 Sep. 2018].
- Renz, A. & Solas, M., 2016. Shaping the Future of Construction, A Breakthrough in Mindset and Technology. [Online] Wwf3.weforum.org. Available at:
http://www3.weforum.org/docs/WEF_Shaping_the_Future_of_Construction_full_report_.pdf [Accessed 27 Jan. 2019].
- Riddell, T., 2017. Mobile Technology Trends the Construction Industry Should be Adopting. [Online] eSUB Construction Software. Available at:
<https://esub.com/mobile-technology-trends-the-construction-industry-should-be-adopting/> [Accessed 14 Apr. 2018].
- Riggs, J., 2003. Materials and components of interior architecture. 6th Ed. New Jersey: Prentice-Hall, p.226 pp.

Sage, 2016. Construction technology outlook. Available at:

http://images.go.sage.com/Web/SageGlobalInstance/%7b9653eb32-62c2-40ba-a0e1-9ffb1c9009bc%7d_2015-sage-technology-survey-infographic-final.pdf

[Accessed 5 Sep. 2018].

Saunders, M., Lewis, P. & Thornhill, A., 2015. Research methods for business students. Johannesburg: MTM.

Schermerhorn, P., 2018. 3 Areas of Construction Tech Launching the Industry Forward.

[Online] Construction Business Owner Magazine. Available at:

<https://www.constructionbusinessowner.com/technology/accelerating-adoption-2019> [Accessed 20 Dec. 2018].

Serra, A., 2017. Crafting the Architectural Measured Drawings. The Plan Journal, 2(1), pp.39-61.

Seubert, C., 2017. [Online] Sciencing.com. Available at: <https://sciencing.com/do-laser-distance-meters-work-6332366.html> [Accessed 17 Apr. 2018].

Shutterstock.com. n.d. Man measuring plasterboard sheet for interior construction.

[Online] Available at: <https://www.shutterstock.com/image-photo/man-measuring-plasterboard-sheet-interior-construction-1173744850> [Accessed 8 Sep. 2018].

Son, H., Park, Y., Kim, C. & Chou, J., 2012. Toward an understanding of construction professionals' acceptance of mobile computing devices in South Korea: An extension of the technology acceptance model. Automation in Construction, 28, pp.82-90.

Statista, 2017. Baugewerbe - WZ 41, 42, 43 – Statista Branchen report Deutschland. Juli 2017. Available at:

- <https://de.statista.com/statistik/studie/id/1907/dokument/branchenreport-baugewerbe/> [Accessed 14 March. 2018].
- Tam, C., 2000. Design and Build on a complicated redevelopment project in Hong Kong: The Happy Valley Racecourse Redevelopment. *International Journal of Project Management*, 18(2), pp.125-129.
- Teddlie, C. & Tashakkori, A., 2008. Major issues and controversies in the use of mixed methods in the social and behavioral sciences. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social & behavioral research* (pp. 3-50). Thousand Oaks, CA: Sage.
- Thomas, H., Mathews, C. & Ward, J., 1986. Learning Curve Models of Construction Productivity. *Journal of Construction Engineering and Management*, 112(2), pp.245-258.
- Thomas, J. & Jennings, H., 2018. The Science of Concrete Homepage. [Online] iti.northwestern.edu. Available at: <http://iti.northwestern.edu/cement/> [Accessed 26 Jun. 2018].
- Vanessa, L., 2018. More about How to Frame a Ceiling for Drywall Update - ipmserie. [Online] ipmserie. Available at: <https://ipmserie.com/how-to-frame-a-ceiling-for-drywall/> [Accessed 8 Sep. 2018].
- Venkatraman, S. & Yoong, P., 2009. Role of mobile technology in the construction industry – a case study. *International Journal of Business Information Systems*, 4(2)
- Villaverde, R., 1997. Seismic Design of Secondary Structures: State of the Art. *Journal of Structural Engineering*, 123(8), pp.1011-1019.

Weippert, A., Kajewski, S., & Tilley, P., 2002. "Online Remote Construction Management (ORCM)." Proceedings of the International Council for Research and Innovation in Building and Construction CIB w78 Conference, 12-14 June, Aarhus, Denmark.

World economic outlook. 2014. is it time for an infrastructure push? The macroeconomic effects of public investment. Washington, D.C.: International Monetary Fund.

Xmentoys, n.d. Hand of instrument technician during function test or preventive maintenance pressure transmitter in oil and gas platform offshore. [Online] Shutterstock.com. Available at: https://www.shutterstock.com/image-photo/hand-instrument-technician-during-function-test-1121866316?src=1r9IXGoGpV_KCRa7opH1Sg-1-9 [Accessed 8 Sep. 2018].

Zentralverband des Deutschen Baugewerbes (ZDB). 2017. Baumarkt 2016. Perspektiven 2017. Available at: [https://www.zdb.de/zdb-cms.nsf/res/Baumarkt2016.pdf/\\$file/Baumarkt2016.pdf](https://www.zdb.de/zdb-cms.nsf/res/Baumarkt2016.pdf/$file/Baumarkt2016.pdf) [Accessed 14 March. 2018]